JOURNAL

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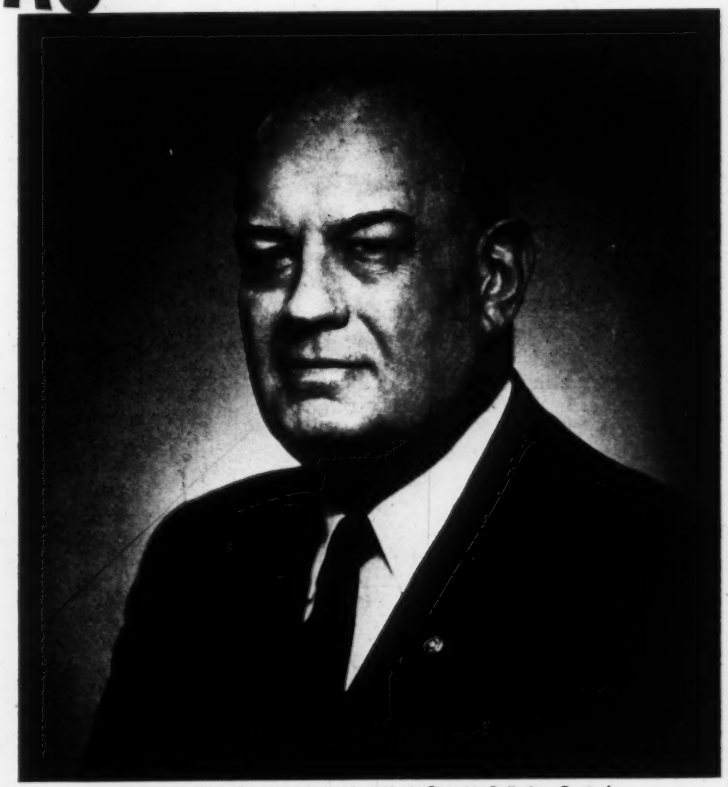

A. J. Benline, Commissioner, New York City Air Pollution Control
Chairman, 54th Annual Meeting of APCA, New York.

How to Evaluate Cottrell Precipitators

How important is Precipitator Size?

A common fallacy assumes a larger precipitator with lower gas velocity is preferable to a smaller precipitator with higher gas velocity.

This assumption overlooks important economies now obtained with:

(a) Efficient voltage application

(b) Specific control of electrical sections

(c) Electrode design improvements

(d) Automatic Rapper Control

(e) Accurate internal baffling

(f) Proper control of gas flow, based on three-dimensional model studies

Close familiarity with these techniques and improvements has enabled us to guarantee 99% collection on large, modern installations.

Applied Voltage

Let's take Applied Voltage as a start. *If you double the operating voltage in a precipitator, it is equivalent to adding three times again as much collecting electrode area—or building a precipitator four times as big.*

If Applied Voltage is this important, how can evaluation engineers make sure a precipitator is operating with maximum voltage at all times?

Generally, the amount of arc-over in the precipitator determines the practical operating limit. Provision should be made in the precipitator's control to measure and integrate this arc-over so it can be used as the motivating factor in the control.

Stated simply, a precipitator must have control equipment which guarantees maximum voltage input regardless of changes in gas flow, particle size or resistivity, etc.

Sectionalization

Another important point in evaluating Applied Voltage is the question of how much sectionalization is provided in the specifications. Gas conditions are not constant throughout any precipitator. Higher efficiencies are obtained if the precipitator is divided into sections, each of which has its own voltage control set. In this way, maximum voltage is applied to each section regardless of variations in gas conditions from one section to another.

Reentrainment

Another factor affecting collection efficiency is the possibility of dust reentrainment. This refers to re-suspension of dust that has already been collected on the collecting electrodes.

Engineers are now demanding proof that collecting plate design provides correct baffling to shield the collecting surface against the sweeping and scouring effects of moving gas streams.

Precipitators using properly designed collecting electrodes can be 25% to 50% smaller than a precipitator using improperly designed electrodes. Once again, the emphasis is on proper design, not precipitator "size".

Proper Rapping

Another cause of reentrainment is improper rapping. A rapping blow that is too hard may dislodge too much collected dust and cause reentrainment. On the other hand, if the blow is too "soft", the dust builds up on the collecting electrodes, disrupts electrical conditions and necessitates reduced operating voltage.

As we said, conditions inside the precipitator are not constant. Gas flow, temperature particle size and resistivity are all constantly changing. Rapping intensity must also change to meet these varying conditions. This means that an evaluation engineer must be sure the rapping equipment specified is fully adjustable to meet all these changing conditions.

Sneakage

Now that collection efficiencies demanded by industry are becoming higher and higher, sneakage is an important consideration. This refers to that part of the gas stream which might sneak around the treatment zone.

Proper internal baffling is the only way to make sure that the entire gas stream flows through the treatment zone. For this, evaluation engineers must rely on the experience of the precipitator manufacturer in three dimensional model studies and research on full-scale precipitators.

Gas Flow Pattern

A major factor affecting the relationship between precipitator size and performance is the gas flow pattern across the face of the precipitator. When you consider the fact that proper flow can mean another 25% - 50% reduction in precipitator size, it pays to investigate the design elements affecting this gas flow pattern. Again, evaluation engineers should ask the manufacturer how he has provided for correct gas flow.

In this brief review we have been able to hit only a few high spots of precipitator evaluation. It is a complicated problem because of the many variables in gas conditions and the combinations of electrical, electronic and mechanical equipment involved.

If you want more information on any of the points discussed in this review, please contact your nearest Research-Cottrell representative or write us in Bound Brook, N. J. Our 48 years of gas cleaning experience are at your service.

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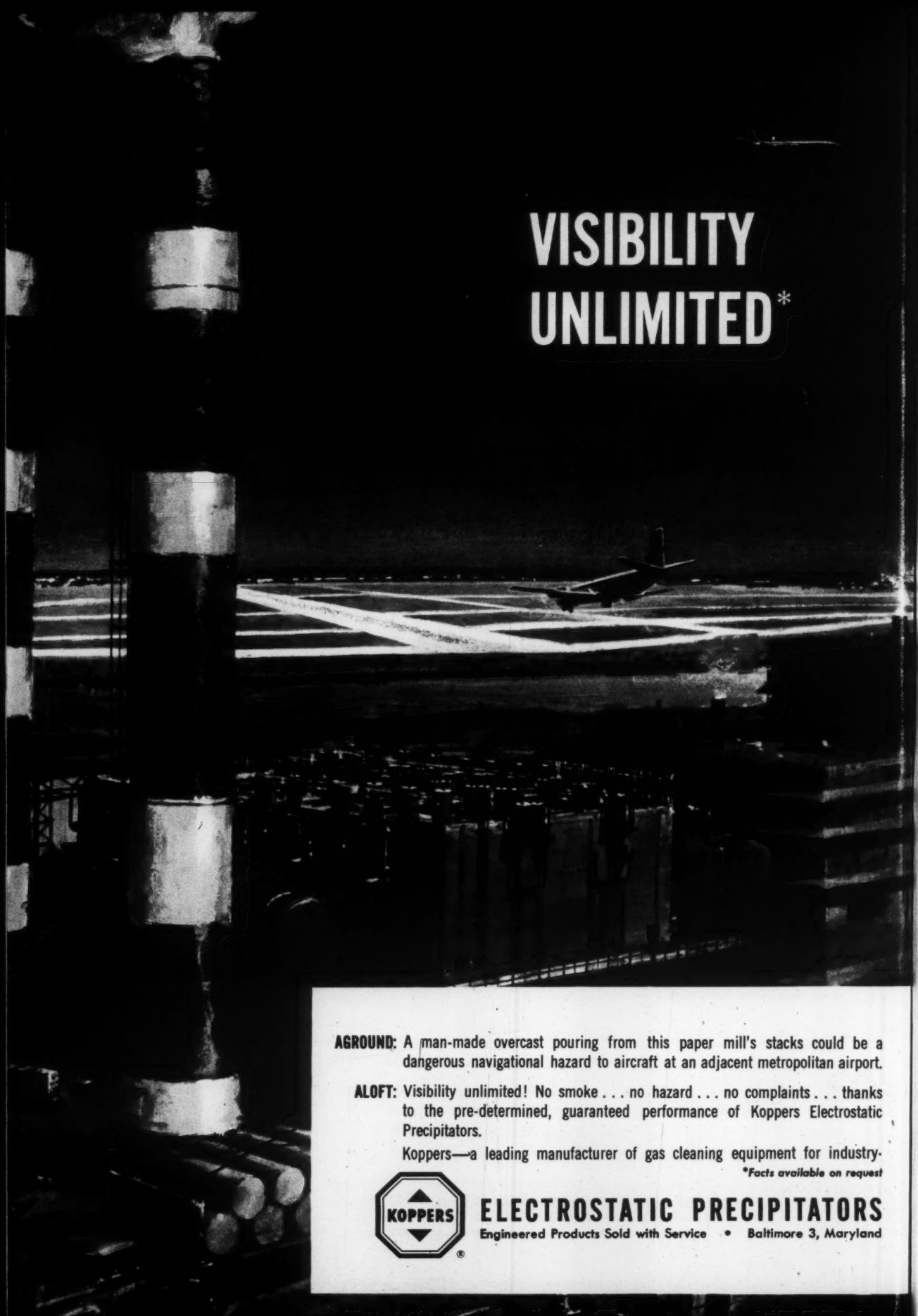

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JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

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Devoted to
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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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(*See page 23*)

SECRETARY'S PAGE

ACTIVITIES IN REVIEW

This issue of the JOURNAL marks an outstanding event in APCA's 54-year history. In expanding the JOURNAL to a monthly publication it is the intention of the Board of Directors to make the JOURNAL a more timely means of communicating with the members. This means then, that the editorial staff will require more news items from its members. Through the medium of this column, we invite APCA's members to send us not only news items but also news releases that now go to the local media. It is our intention to publish new columns monthly headed "News from the Control Agencies," News from Industry," and "Technical Council News."

Technical Council Meets

The Technical Council held its semi-annual meeting at the Mellon Institute in Pittsburgh on Tuesday, November 15, 1960. Some of the items accomplished during the day are as follows:

1. Council recommended to the Board the formation of three new committees as integral committees of the technical council; they are: Vehicular Exhaust, Economic Effects, and Radiation.

2. Council recommended that four other new committees be established by the Board as service committees; they are: Planning and Zoning, Consultants, International Affairs, and Education and Training.

Machinery set up by the technical council to elect five members for a steering committee, annually. A nominating committee is to be appointed by the chairman of the council prior to the annual meeting. The nominating committee is to be instructed to maintain continuity of the steering committee. This should result in the new chairman of the council annually being selected from the most active technical co-ordinating committee chairman.

4. Recommended clarification to the Board of final action on the status of technical reports published in the JOURNAL. Final action on this matter awaits Board approval.

5. Council recommended re-designation of the TA-6 Committee from "Stoker" to "Coal Utilization."

6. Council recommended to the Board de-activation of the TA-1 Steam Heating Equipment Committee.

7. Council recommended to the Board, re-designation of the TA-4 Oil Burners Committee to TA-4 Oil Burners Equipment Committee.

8. Council recommended the combination of TI-7 and TI-9 Ferrous and Nonferrous Committees.

9. Council recommended re-designation of TA-9 Power Boiler Committee to Power Boiler Equipment Information Committee.

10. Progress reports were heard from 10 technical committees' chairmen.

Three New Committee Chairmen Named

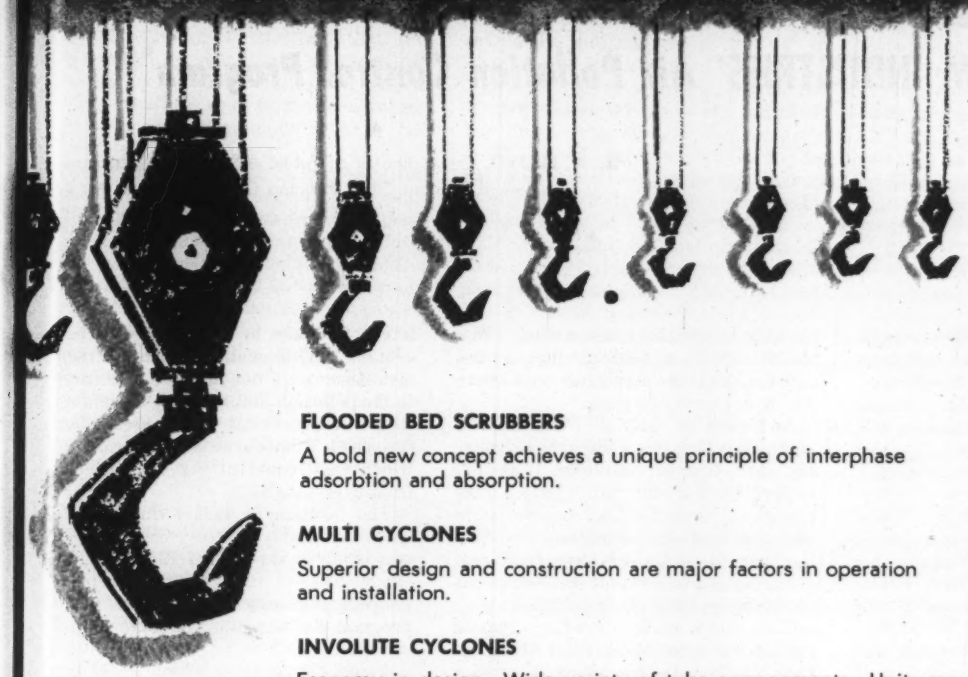
As a result of the re-alignment of committees, Ernst P. Hall, of Consolidation Coal Company, has been named chairman of the TI-4 Coal Committee. Harry C. Ballman, Director of Air Pollution Control Division of National Coal Association, has been named chairman of the TA-6 Coal Utilization Committee. Harold L. Barnebey, of the Barnebey-Cheney Company, has been named Chairman of the TA-7 Odor and Gas Treatment Committee.

Future of APCA Committee

Liv Ireland's Committee has held its first meeting and has designated missions for each committee member. Technical Co-ordinating Council Chairmen have been furnished names of volunteers for committee work. The response was most gratifying since 800 replies were received from 1850 members canvassed.

(*Continued on p. 48*)

Specific Engineering Applications For Industry



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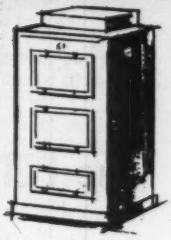

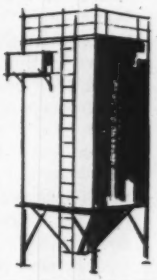

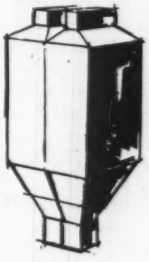

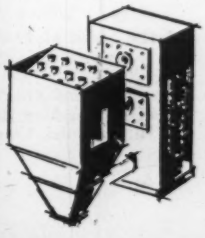

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The PETROLEUM INDUSTRIES' Air Pollution Control Program*

G. A. LLOYD, Co-ordinator of Public Affairs, Esso Standard, Division of Humble Oil & Refining Co., New York, N. Y.

I want to tell you gentlemen right at the start that I am *not* an air pollution expert. Such experts were nonexistent as little as ten years ago. They're still as scarce as hen's teeth—which is one of the reasons I'm here today.

I won't belabor this point because I remember the occasion when Thomas Mann first visited America. While talking with the novelist one of our well-known authors emphasized again and again that he was a mere hack whose work was not to be mentioned in the same breath with that of the master. Mann listened with infinite patience. But when the party was over he turned to his host and said; "That man had no right to make himself so small. He's not *that* big."

With that point in mind, I'll confine myself to saying that, if you start shooting technical questions at me when I finish, I'll probably have to refer a lot of them to "higher authority."

Although not an air pollution expert, I *am* familiar with communication methods. For the past 15 years, part of my company job has been to generalize highly technical data to the point where average folks can distinguish the scientific forest from the trees. More recently, as chairman of the Information Committee of the American Petroleum Institute's Smoke and Fumes Committee, I have had to make myself acquainted with basic air pollution problems, and with methods being developed to find solutions for those problems. So what I'm going to do is try to give you the broad picture.

When the API decided, in 1952, to sponsor a program of research in the field of air pollution, the Los Angeles smog problem had, as you know, been in the headlines for several years. That's not to say the problem was a new one. Far from it. In 1834, Richard Henry Dana, famed author of "Two Years Before the Mast," wrote in his diary: "I have this day returned from the plaza at Los Angeles and did go to the sick bay with eyes smarting. The pharmacist's mate tolde me this was not unusual, and the navigator said there was a dammed inversion."

And even as early as 1542, only 50 years after Columbus discovered America, the Spanish explorer, Cabrillo, noticed that smoke from Indian fires spread out over the Los Angeles basin and obscured the mountains . . . You might say those Indians were sending up smoke signals to warn future generations about the hazards of air pollution!

The rapid growth of Los Angeles during and after World War II aggravated its longstanding smog to a point where the public began insisting that something be done immediately to abate a nuisance that was reducing visibility, irritating eyes, damaging plants and causing runs in women's hosiery. In 1950 the Los Angeles County Air Pollution Control District was organized and placed in charge of a man who had occupied a major role in cleanup campaigns conducted at St. Louis and Pittsburgh.

The District authority embarked at once on a program to clean up Los Angeles by methods that had been effective in these other two cities. The results are well known. The smog got worse and the public outcry became more and more vehement.

In short, when the American Petroleum Institute entered the picture the public was in a highly excited emotional state, the newspapers were strident, and even the scientists were puzzled.

API Looks at Problem

It was at this point that West Coast oil people who had been working on the problem decided that an expanded, objective study of air pollution was essential. Because the tension showed signs of spreading to urban centers in other parts of the country, they brought the problem to the American Petroleum Institute.

Discussions in API reached the conclusion that the whole petroleum industry has an interest in community air pollution abatement because its installations operate in hundreds of urban centers. While many oil men felt their operations were not major contributors to the pollution problem they recognized that their national trade association furnished a mechanism by means of which they could attack the problem from every angle.

The decision to tackle this complicated and highly controversial situation was made at the end of 1952, and, by the middle of 1953, a comprehensive program of research was started. This program was based on the following assumptions:

First: Urban air pollution is disturbing to people but few are aware of its cause or cure.

Second: Scientists have advanced many conflicting theories on the subject, but there are few available data to support any theory.

Third: Effective abatement measures can be adopted only after the nature of the problem is understood.

The API set out, therefore—not on a crash program—but upon a long-range basic research study designed to find out, if possible, just what chemicals or trash go into the air and what happens to them after they become a part of our environment and how these facts relate to our troubles and irritations.

The answer to this question obviously required the establishment of many projects to look into the chemistry of polluted air—projects conducted by the best scientists and research institutions available.

The nature of chemicals identified by such projects eventually indicated that a major source of urban air pollution might well be the exhaust gases from motor vehicles. This conclusion was supported by a number of general observations, such as formation of smog clouds over main arteries of traffic in the Los Angeles basin. The same phenomenon was observed elsewhere. But there is no major city in the United States where the ventilation is so limited as it is in Los Angeles and very few that are subjected to such intense ultraviolet. Thus the effects of many chemical reactions that take place in

* Presented at the 53rd Annual Meeting of APCA. May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

urban atmospheres are less dramatic in other areas than in Los Angeles.

Similar observations, none of which should be credited entirely to the API, called attention to the fact that the sources of air pollution were not to be found exclusively in industrial plants. They result, as well, from the activities of every man, woman, and child in this country.

Such findings made it necessary for the API, and other organizations that had started air pollution studies, to conduct more precise investigations into the content of motor vehicle exhausts. The API was assisted in this work by the Automobile Manufacturers' Association through a long-established joint research organization known as the Co-ordinating Research Council, Inc. It was immediately found that the most formidable problem faced by scientists seeking to separate exhaust gases was that of developing tools with sufficient precision to make detailed analyses.

Long before such tools could be developed, automobile companies recognized that they were faced with an equipment problem. They set about the development of scavenging devices that would clean up materials that fail to burn in engine cylinders.

This work on scavenging devices such as afterburners is progressing steadily. There are at least 40 organizations in the race to develop a low-cost effective afterburner. You can be confident that the problem of automobile exhaust eventually will be solved. It will *not* be solved quickly enough to please some, but I believe we can agree that the present situation still presents no basis for grave concern and unsound abatement measures.

Sponsors Many Investigations

While the above developments were in progress the API sponsored a number of other investigations. I will return to these later but right now I want to talk about the creation of entirely new scientific tools for research. You see, it wasn't enough to build some entirely new gadgets that would measure chemicals in the air around the few parts-per-million range. Research experts with a knowledge of meteorological phenomena and a skill in the use of highly complex mathematical formulas also had to be found or developed. In one case, for example, it took an API committee two years to find a man competent to do one particularly exacting job.

Studies of this complexity cannot, as you know, be carried to successful completion by the garden variety engineer. In fact, the study of air pollution may lead to the establishment of a new profession called micro-meteorology. There are mighty few micro-meteorologists in the world today and at this stage of the game I gather they have a pretty good thing for themselves. I am going to stick out my neck and predict that, before many years pass, their extremely practical work will be in even greater demand than it is right now.

So far, I have talked in generalities to give you an inkling of the complexities involved in air pollution research. Now I want to become more specific regarding the individual projects sponsored by the API after it had made a thorough investigation of the capabilities of America's leading research institutions. Since you gentlemen are for the most part practical engineers, I'm quite sure you are most concerned with a rundown on steps that have been taken, or soon may be taken, to alleviate if not cure this annoying and growing blight.

Approaches to Cure Found

So far, I regret to say, research that has cost the API more than $1.3 million through 1959 has developed no cure. On the other hand, explanations found regarding the basic nature of the problem have opened up a number of approaches to such a cure.

An early result of API-sponsored research at The Franklin Institute was confirmation of a theory that the exposure to intense sunlight of a mixture of hydrocarbons and nitrogen dioxide, such as is present in automobile exhausts, could produce ozone. This substance, which laymen think of as a harmless and rather refreshing aftermath of thunderstorms, can, as you well know, become highly irritating when present in sufficient concentrations. And such concentrations are present in the air of Los Angeles when an inversion clamps down.

The ozone reaction theory originally was developed by Dr. A. J. Haagen-Smit of the California Institute of Technology. Development at The Franklin Institute of a long-path, infrared cell known familiarly as "Silent Sam, the Smog Detective," made possible a closer study of this and other reactions. Shortly thereafter, a simple and portable instrument for determining trace quantities of ozone was studied by the Armour Research Foundation under an API grant.

In the course of experiments with "Silent Sam," a series of strange lines was observed in the infrared spectra of some synthetic exhaust gases which indicated the presence of a new substance. At first, this mysterious material was simply called "Compound X." Later, its structure was tentatively determined as peroxy acyl nitrite and it became of considerable assistance in determining the mechanism of the hydrocarbon-nitrogen dioxide-sunlight-ozone reaction.

Until last year, "Compound X" was considered an interesting intermediate product of the smog reaction, but probably not a direct contributor to any of smog's irritating characteristics. Then newly-developed equipment made it possible to isolate sufficient quantities of the material to permit its exact nature to be determined. Much to everyone's surprise, it turns out that "Compound X" *is* a very potent cause of both plant damage and eye irritation.

That is only one sample of the complications that arise continually during the course of the API program. Here is another:

Studies of automobile exhaust gases, before and after they were exposed to sunlight, disclosed that materials in those exhausts which irritate the eyes are not necessarily those that cause plant damage, and vice versa. This research also showed that there *are* several compounds in the air that cause both plant damage *and* eye irritation. Such conflicting discoveries are enough to make any researcher beat his head against the wall.

SO_2 Not Only Culprit

Then, during the early years of the program, projects at the University of Illinois proved that the very slow oxidation of sulfur dioxide to sulfur trioxide in the air made only an insignificant contribution to the smog phenomenon. There had been a widespread belief that this reaction was a primary cause of reduced visibility in Los Angeles and some other cities. After examining all the evidence Dr. Maurice Goldblatt, consultant for the API's Medical Advisory Committee, concluded, however, that the sulfur dioxide content of Los Angeles air could not reasonably be considered, *in itself*, a cause of anxiety.

In 1959, further work pointed the finger of suspicion at sulfur dioxide from an entirely different direction. Now it seems that introduction of minute quantities of this substance into a hydrocarbon-ozone, or hydrocarbon-nitrogen dioxide system exposed to bright sunlight, may cause development of an aerosol that can reduce visibility! These reactions were studied under laboratory conditions, however. Whether aerosols are formed in the atmosphere by any or all of such reactions remains to be investigated.

Over the years, work sponsored by the API has made other contributions to a partial understanding of such exasperating problems. These contributions include:

A technique for tracing the path of material discharged from a single source, such as an incinerator or smokestack, which takes into account the weather conditions influencing such a path.

A study of meteorological phenomena as they affect air sampling.

Contributions to methods for analyzing the many hydrocarbon compounds in automotive exhausts

A study showing that domestic and industrial furnaces burning gas or oil discharge very minor quantities of hydrocarbons, even under poor operating conditions.

Research into the atmosphere over representative cities which disclosed that the high ozone content typical of Los Angeles smog is *not* characteristic of other localities. An interesting result of this project has been proof that the sulfur dioxide content of Los Angeles air is *much lower* than that of other cities studied. In fact, it is indicated that a high ozone level cannot persist in the presence of a high sulfur dioxide content!

Another investigation, carried out in co-operation with the Air Pollution Foundation, pointed to the conclusion that no single fuel, or fuel property, is entirely responsible for pollution caused by auto exhausts.

On the basis of present knowledge, no responsible scientist would claim that one type of gasoline produces significantly more smog than another. This means, in turn, that legislation designed to regulate the olefin content of gasoline will have little or no effect in reducing smog. Its only result probably will be to increase the cost of gasoline to motorists.

In all fairness, I must add that this question of gasoline composition is far from settled. Extensive work on the problem is being continued by the API and other interested organizations.

Condition of Motor Important

One result already obtained is proof that eye irritation, visibility reduction, and ozone formation from exhausts are affected much more by differences in automobiles than they are by differences in fuel composition. A car with dirty spark plugs, a too-rich fuel mixture and faulty piston rings belches immeasurably more pollution than a well-maintained vehicle, no matter what brands of fuel they both use. One misfiring plug may double the average hydrocarbon concentration of an exhaust. A *set* of fouled plugs can increase the rate of hydrocarbon emission more than two and a half times during wide open throttle acceleration!

The sometimes-conflicting findings of all of these research projects show that the nature of air pollution and its effects, remain extremely complex, even after years of hard work by some of the nation's leading scientists. A great many things must be more clearly understood before a permanent solution can be obtained. Under such circumstances, the API is continuing its research as a long-range program exploring many facets of the situation, including the effects of air pollution on agriculture, industry, and the public health.

This broad approach is maintained for two reasons: In the first place, oil companies, being responsible citizens, need every bit of information they can obtain in order to keep their plants from giving offense to communities in which they operate. In the second place, those companies firmly believe that real progress may be made by means of basic research into the mechanisms and chemical reactions involved, as well as into the meteorological conditions that exist over various urban centers. Only by collecting such data, and making it available to people like you for intelligent and realistic use can expensive, wasteful efforts at abatement by avoided.

A case in point is the early effort to apply measures that had been found effective in Pittsburgh and St. Louis upon the Los Angeles situation. Because weather and other conditions were different on the West Coast, this endeavor resulted in failure.

The same thing has happened in other areas that "lifted" abatement legislation without proper study and tried to apply it to their local situations.

One of the most ridiculous of these cases occurred when a town located 100 miles from any navigable stream copied a good St. Louis ordinance that banned smoking stacks on Mississippi River steamboats.

So much for the results, to date, of API's research program. I'd like now to discuss the Institute's recent efforts to communicate its findings to oil company management and employees, to air pollution control officials and to the general public.

From its organization in 1952 until the beginning of last year the Smoke and Fumes Committee devoted itself, as I have said, to basic research. Findings were reported promptly to the scientific world through the journals of professional societies, but no effort was made to communicate with the public during those formative years. It was agreed that researchers and committeemen should work rather than talk, and that talk should be postponed until there was something to talk about.

Public Relations Men Included

Nevertheless, several public relations men were included on the membership of a Smoke and Fumes Publications Committee. They were placed there to familiarize themselves with problems under study so they might be ready to play a larger role at the appropriate time.

When the nature of the air pollution problem had been sufficiently defined by research to justify the release of information to the public, the Institute took steps to meet this changed situation. In the Spring of 1959 the Technical Publications Committee was reorganized as the Information Committee and additional public relations men with oil industry backgrounds were added to its roster.

The information Committee of which I am chairman understood clearly that it is one thing to unearth pertinent facts and call them to the attention of professionals such as you gentlemen and an entirely different thing to get the general public to appreciate the meaning of those facts. How can people judge the need to purchase afterburners for their cars unless the latest findings about automobile exhausts have been explained to them in layman's language? What good does it do to prove to air pollution officials and legislators that oil refiners have vastly reduced emissions from their stacks and flues if the public doesn't known what has been done?

Public Must Be Informed

This is just another way of saying that if scientists, control officials and representatives of industry are to make full use of research findings to establish adequate controls they must have the backing of an informed, understanding public. Such backing will help to prevent unsound legislation, duplication of effort, waste and "wheel spinning" at all levels.

The Information Committee, therefore, was given responsibility for developing the best possible relations with the public and also with oil company personnel, since the latter's co-operation is essential in implementing the entire abatement program. The committee's basic object was defined as, and I quote, "to recommend remedial activity." Its specific objectives are:

First: To collect, evaluate, and integrate information about six pollution problems facing the industry, the attitudes of the general public on these problems, and the activities of individuals or groups seeking to achieve objectives in this field.

Second: To keep the Smoke and Fumes Committee informed on problems of concern to the public and provide assistance in making decisions concerning the entire program.

Third: To promote better understanding and appreciation of oil industry research efforts in air pollution problems.

Fourth: To develop, through appropriate API channels, a flow of information to oil industry personnel on the subject of air pollution as rated to the industry.

Fifth: To assist in preparing statements on controversial issues in the field of air pollution for distribution to the public through companies that receive inquiries from any source.

The first result of our program in 1960 was publication of this bibliography of all API research papers relating to air pollution.

We also have collected and adapted materials previously used by oil com-

(*Continued on page 44*)

CONTROL OF ODORS *from a Continuous Soap Making Process**

JEROME E. MOLOS, Acting Chief, Industrial Hygiene Section, St. Louis Health Division, St. Louis, Mo.

A quiet, semi-residential neighborhood in south St. Louis suddenly, in the spring of 1957, became a focal point of air pollution complaints. The complainants, all householders, described the pollution as an obnoxious, fishlike odor which tended to persist for long periods, permeated their residences and yards, and was a general nuisance in interfering with enjoyment of their homes and neighborhood. Observations by Health Division personnel, in the general area of complaints, substantiated the condition described above. Tracing the odor from the points at which it was faint to the area where it was pronounced, suggested strongly that a soap plant, which had been located in the neighborhood for many years, was the source of this odor.

Management was contacted, and a preliminary survey was made of the plant. From this investigation it was found that the company had been a formulator of soap compounds for many years at its present location. Soap, manufactured elsewhere, was purchased in carload quantities. To the soap was added scrubbers, modifiers, perfumes, etc., to get finished products.

The company subsequently decided to manufacture its own soap. To do this the company installed a unique, continuous, countercurrent, three-stage process to make neat soap from coconut oil, tallow, soybean and cottonseed soap stocks. A large spray drier was erected to make granulated soap from the neat soap. To the best of our knowledge, there are few comparable plants in the country.

Break-in processing with the new equipment commenced in the spring of 1957, exactly coinciding with origination of complaints. Much of the rest of 1957 was spent in "working out the bugs" in the new process and little continuous processing was done that year. However, by 1958 the company began full scale operation of the process, operating continuously for eight or more hours per day. An avalanche of complaints of odors responded to the increase in processing.

The soapmaking process was quite unique, and no one locally had experience with a comparable problem. Consequently, a survey of the literature was made and leading official air pollution agencies and private companies were contacted in the hope that someone had experience in controlling a similar process. No contributory experience was forthcoming. This being the case it was necessary to start from scratch, and the purpose of this paper is to enable others to handle a similar situation without the unusually heavy expenditures of time, energy, and money required in this instance.

The Soapmaking Process

A review of the soapmaking process should assist in understanding the air pollution problem which resulted from it. Four types of fats or oils are processed, namely coconut oil, tallow, soya soap stock (foots from recovery of soybean oil), and cottonseed soap stock (foots from recovery of cottonseed oil). The coconut oil and tallow are triglycerides of the general formula:

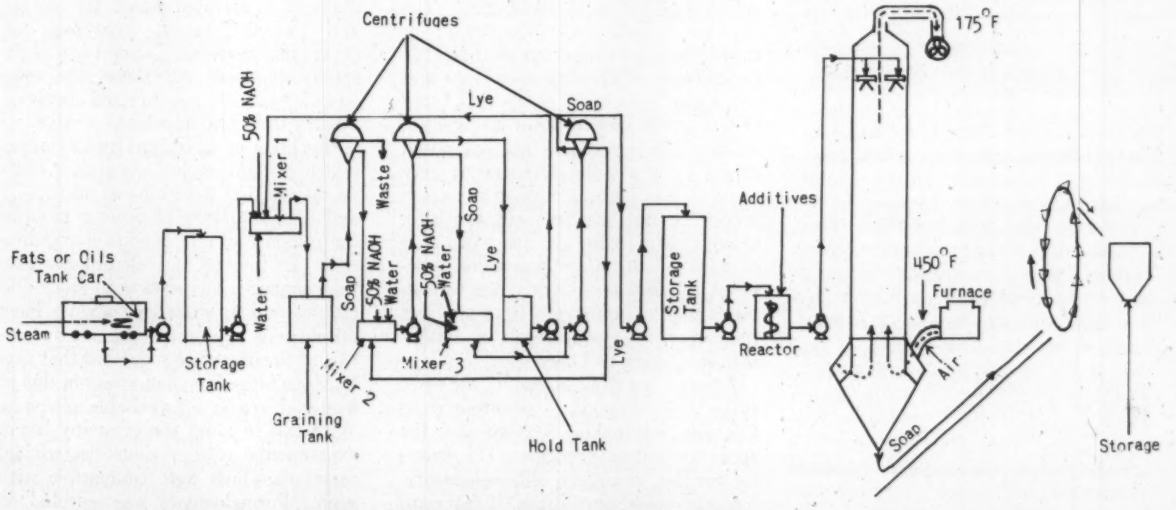


Fig. 1. Flow diagram of the three stage, continuous, counter current Sharples soap making process and the spray tower drying process.

* Presented at the 53rd Annual Meeting, of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

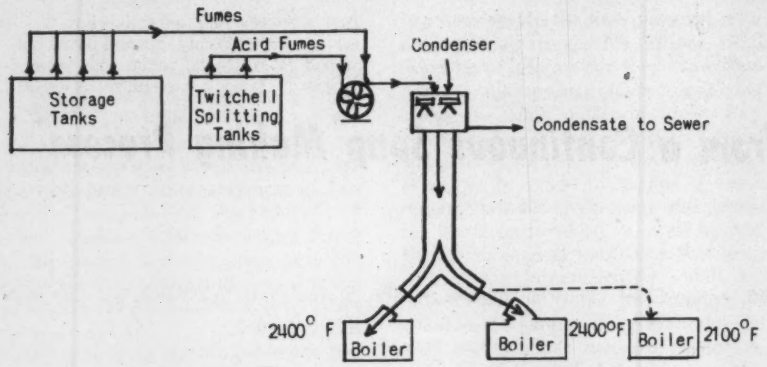
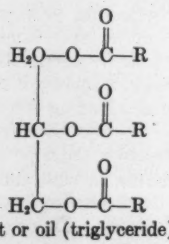
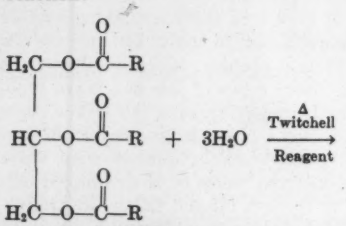


Fig. 2. Control of vapors from storage and Twitchell splitting tanks.

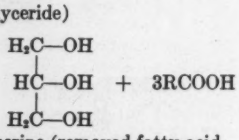


fat or oil (triglyceride)

with R being long chain aliphatic hydrocarbon radicals. Prior to the soapmaking process, the triglycerides are split by means of a Twitchell reaction. This process takes place in large steam-heated vats according to the following reaction:



fat or oil (triglyceride)



glycerine (removed fatty acid and reclaimed)

The fatty acid is now ready for introduction into the Sharples soapmaking process where it is converted to the sodium salt (RCOONa), which is soap.

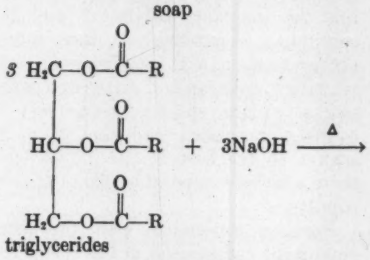
The soya soap stock and the cottonseed soap stock do not require the above treatment since they already contain a significant percentage of free fatty acids. The total composition of these soap stocks, as received, is as follows:

1 RCOONa (soap)
2 RCOOH (fatty acids)
3 triglycerides
4 glycerine
5 nitrogenous constituents (protein matter)

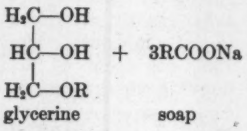
The soya or cottonseed soap stock is fed directly into the Sharples process where the following reactions occur:

1 RCOONa (unchanged)

2 RCOOH (fatty acid) + NaOH ⟶ RCOONa (soap) + H_2O



triglycerides



glycerine soap

4 glycerine (unchanged)

5 nitrogenous constituents ⟶ proteins, urea, ammonia, amines

From an air pollution standpoint reaction 5 is the most significant. The chemical reactions for formation of these nitrogen compounds are not fully understood. Only soya soap stock and cottonseed soap stock of the four types of fats or oils used contain nitrogenous matter. In view of this fact, one would expect odor complaints to occur only when soya or cottonseed soap stock was processed, but this was not the case. Odors were detected at times when only coconut oil or tallow was being processed. This was evidently due to contamination of equipment from previous runs when soya soap stock or cottonseed soap stock had been used.

Figure 1 is a flow diagram of the three stage, continuous, countercurrent Sharples soapmaking process and the spray tower drying process. The Sharples process is largely self-explanatory. The high speed centrifuges (15,000 rpm) are used to separate the soap and aqueous phases. Neat soap from this process is pumped to the reactors and then to the top of the tower where it is sprayed into the tower. At the same time, approximately 10,000 scfm of air, heated to 450° F by a furnace, is blown into the bottom of the tower. Drying occurs, and the soap granules drop to a hopper at the bottom of the tower where they are removed. Moisture laden air, together with some soap fines, is exhausted at 175° F from the top of the tower.

Early Investigation and Control Efforts

Since it was apparent that very little outside help was to be had in the solution of the odor problem, it was decided that the plant operations should be carefully evaluated to determine which of them were odor sources. This was easier said than done. For, even though the amine-like (fishy) odor was very obnoxious in the neighborhood of the plant, at higher concentrations within the plant, it tended to quickly deaden the sense of smell. This made it virtually impossible to determine the exact odor sources by odor perception. To further complicate matters, the odor tended to adhere to surfaces such as skin and hair, clothing, automobiles, etc., for extended periods of time. As a result, persons, who had been in the plant for a period of time, would continue to perceive the odor for many hours even though miles from the plant. Odor impregnated clothing required laundrying or dry cleaning to completely remove the odor.

Despite these handicaps, careful study of the plant operations suggested that the following ones were most likely involved in creating odors: the three stage centrifuging operation, which, for operational reasons, could not be totally enclosed; the spray tower drier which discharged steam-laden air to the atmosphere at an elevated point; the storage and Twitchell tanks. Practically all other processes and operations were totally enclosed. Of these, the company felt that the centrifuging operation was the most important odor source.

One point of agreement by all competent investigators, including plant engineers, was that the odor was principally amine. Formation of amines requires the presence of nitrogenous contamination. Of the fats and oils processed by the company, only soya soap stock and cottonseed soap stock are known to have nitrogenous contaminants. Investigation of the literature suggested that perhaps the formation of amines was due to bacterial action on available nitrogen. With this in mind the company began experiments with various bactericidal materials which were compatible with soap. Formaldehyde was selected as most suitable, and low percentages of it

Fig. 3. Vapors from storage and Twitchell splitting tanks ducted to air intakes of steam generators.

were used to treat soya stock in an effort to sterilize it. This was abandoned when no significant improvement in area-wide odors could be demonstrated.

Other attempts to reduce odors were subsequently tried. One of these was installation of steam vapor condensers on storage and Twitchell tanks. This, too, proved ineffective. Then, in the summer of 1958 the company installed a ventilation system for the centrifuge room. This consisted of hoods above each centrifuge connected to a common duct, which was connected to a wet scrubber. The scrubber, consisting of a series of baffles and spray nozzles, was connected to an exhaust fan. Fine sprays of weak boric acid solution were used as the scrubbing medium. By using a damper system all of the air passing through the scrubber could be returned to the centrifuge room, or part of all of it could be discharged to the atmosphere. The boric acid solution was recirculated adding fresh make-up acid as required. Once again significant reduction in odor levels could not be demonstrated with this system.

Various modifications of the scrubber system were made including use of water instead of boric acid. In addition, a sweet smelling odorant compound was sprayed into the scrubber discharge stream in an effort to sweeten or modify the amine-like odor. The resulting odor was somewhat modified though still objectionable. Professional observers could easily distinguish the two odors in the neighborhood of the plant indicating that they tended to separate in the atmosphere.

Odorants were also sprayed into the discharge from the spray tower drier. Ducts were constructed to connect the storage and Twitchell tanks to the scrubber system. Even modification of the soapmaking process itself was attempted. A new type of centrifuge was tried; operating the process at lower temperatures to reduce vapor pressures was tried. Yet, in spite of all this, complaints continued and the odors remained objectionable.

With each failure, protestations from neighborhood residents mounted. They appealed to their aldermen to bring legal action against the company under the provisions of the City air pollution ordinance. A group of citizens paraded in front of City Hall, with placards, protesting about the odors and appealed to the Director of Public Welfare to take action in their behalf.

In an effort to learn more about the nature and characteristics of the odor and to evaluate the efficiency of the scrubber when using boric acid, air samples were collected at strategic points in the plant. The sampling locations chosen were: (1) the centrifuge room, (2) in the ductwork leading to and from the boric acid scrubber, and (3) the discharge from the spray tower drier.

Samples from the centrifuge room were collected in bubblers using a 2% sulfuric acid solution. An ether-chloroform extraction was made on the samples, and the solvent was then evaporated from the extract. The odor of the residues was the same amine-like, fishy odor which had become so familiar. In addition the residues were greasy, water insoluble, did not react readily with concentrated ammonia as would a free fatty acid, and were saponifiable with alcoholic potassium hydroxide, the product from which was soluble in water and exhibited the physical appearance of a soap solution. In short, the residues were evidently quite odorous fats or oils.

Similarly, samples were collected at both the feed and discharge ends of the boric acid scrubber using distilled water in the bubblers. To no one's surprise, no significant difference was found in these samples, indicating that the air was not being effectively scrubbed. The pH of the samples was about the same before and after the scrubber averaging 8.4 compared with pH 6.2 for the distilled water blank. Normally water exposed to air will tend to become more acid. The samples were distilled and distillates neutralized with hydrochloric acid and evaporated to dryness. The distillate residues were then recrystallized from alcohol to give leaflike, colorless, deliquescent crystals similar to methylamine hydrochlorides. Unfortunately, equipment for the determination of micro-melting points was not available.

The pronounced fishy odor of both the aqueous and solvent solutions and the distillate, and its removal by acid is indicative of amines. This is further supported by the formation of a hydrochloride with HCl. Tests for aldehyde proved negative. Of greatest significance was the finding that very dilute nitric and hydrochloric acids removed the odor from the samples, whereas boric acid was ineffective.

To summarize these findings, the fishy odor appeared due to the presence of low boiling point amines which were not effectively scrubbed out in the boric acid scrubber. The ultra-centrifuges appeared to create oil aerosols which seemed to act partially as a carrier for the amines. It is, however, quite possible that the formation of the oil aerosol and the escape of the amines

Fig. 4. Spray tower drier.

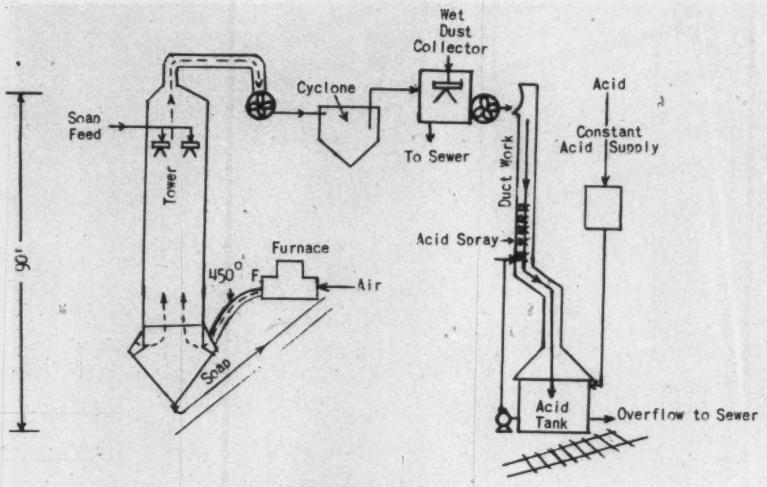


Fig. 5. Control of odors from spray tower drier.

were quite independent of one another.

Samples were collected at the discharge from the spray tower drier using 2% sulfuric acid in the bubblers. The samples were extracted with chloroform and ether, and the solvent extract was then evaporated. No pronounced or offensive odor was detectable from the residues. It would appear from this that the spray tower drier was not a source of odor. It was impossible to accept this conclusion since objectionable odors were detected downwind from the plant on numerous occasions when only the spray tower drier was in operation. Furthermore, detection of the odor at greater distances from the plant, five to six mi, suggested an elevated source, i.e., the spray tower drier.

The explanation for this apparent paradox appears to be the elevated temperature (175° F) of the spray tower discharge stream. At this temperature considerable evaporation occurred in the bubblers which required replenishment of the sulfuric acid solution from time to time. It seems entirely possible that the low boiling point amines were simply not collected under these conditions. It was felt that had the samples been collected using the same bubblers submerged in an ice bath, amines would have been collected just as they were at the other sampling locations.

Examination and study of the laboratory findings and odor observation data led the company to disappointingly conclude that, despite expenditure of considerable time, energy, and money, the odor problem remained substantially unabated. Moreover, unceasing public pressures resulted in the following developments: (1) an aldermanic public hearing on air pollution at which the soap company was a prime target; (2) a series of public hearings called by the Health Commissioner to enable him to determine if the soap company operations were resulting in violation of the air pollution ordinance.

With this background in mind, the company decided to concentrate all further efforts on the three sources which seemed largely responsible for the odors, the storage and Twitchell tanks, the spray tower drier, and the centrifuging operation. The manner in which these odor sources were finally successfully controlled follows.

Control of Odors from Storage and Twitchell Tanks

All storage and Twitchell reactor tanks (Fig. 2) were carefully sealed except for a vent. The vent from each tank was led into a completely sealed duct which led to a condenser (which removed steam); and thence to the steam boiler room. An exhaust blower connected to the duct system produced a small vacuum on each tank.

The duct to the boiler room was led directly to the air intakes of the steam generators (Fig. 3). The air requirements of the steam generators (3000 ft³/min) were substantially in excess of that delivered by the duct (250 ft³/min). The vapors from the tanks are burned in the steam generators at approximately 2400°F., which was considered fully adequate to insure complete combustion of the organic contamination.

Other control provisions were made to complement those already described. The wash water from the steam condenser was led directly to the sewer. All openings to the boiler room were sealed, and steel fire doors were kept closed except for one to allow for the additional air requirements of the steam generators (approximately 2750 ft³/min). Dampers were installed in all steam generator exhaust stacks so that if any of the generators were not in operation, there could be no draft from the boiler room through the generator's intake, to the stack, and thence to the atmosphere above the boiler room.

Control of Odors from Spray Tower Drier

The spray tower drier (Figs. 4 and 5) was completely sealed to the outside atmosphere to prevent escape of odors. As originally designed exhaust air from the spray tower was passed through a dry dust collecting system to collect carry-over soap fines. This was changed so that now the exhaust air passes through a water spray (wet) system after the dry collector (Fig. 6) and all wash water is led directly to the sewer. This, of course, eliminates carryover of soap particles.

Formerly, moisture-laden air from the spray tower was discharged directly to the atmosphere, after passing through the dry collectors. The point of discharge was approximately 90 ft above ground. Now, after passing through the water wash system, air discharged by the tower is ducted to a stainless steel tank located at a railroad spur at ground level.

The stainless steel tank contains a solution of a strong inorganic acid, sulfuric, which is maintained at approximately pH 2. The acid concentration is maintained by means of an overflow system, adding fresh acid continuously.

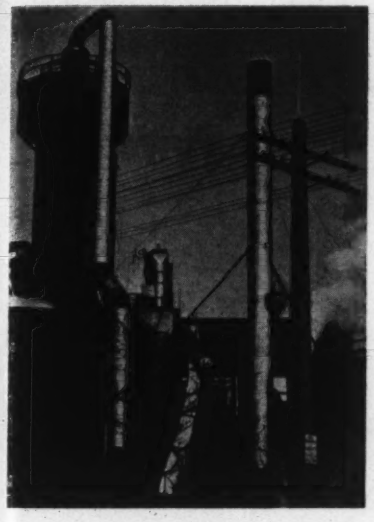


Fig. 6. Dry and wet collectors for spray tower drier soap fines. Ductwork carrying odor-laden vapors to acid sprays and thence to acid tank.

From the stainless steel tank the acid solution is pumped under 30–60 lb of pressure to spray nozzles located in the tower duct approximately 40 ft above the tank. Exhaust air from the tower passes directly through the sulfuric acid mist, and then the air, together with the mist, travel 40 ft through the duct to the stainless steel tank below. The stainless steel tank is hooded and baffled so as to permit discharge of scrubbed air without acid mist carry-over. Thus, instead of discharging unscrubbed spray tower exhaust air to the atmosphere 90 ft above ground level, acid scrubbed air is now discharged at ground level.

Other control provisions were made to augment those already described. Pressure gages were installed at convenient points to enable inspectors to determine if spray nozzles had become plugged. A large glass peephole was installed in the duct to permit visual inspection of the spray nozzles to determine if they are operating effectively and efficiently. The glass peephole was made removable in the event that nozzle maintenance was necessary. All piping and tubing to the spray nozzles were steam traced to prevent freezing. The spray nozzles were also connected to an air compressor so that 150 psi of compressed air could be used to blow out the spray nozzles to keep them from becoming plugged. The nozzles are routinely blown out several times each day to insure continuous, uninterrupted spraying of the sulfuric acid solution.

Control of Odors from Centrifuging Operations

Originally, odor laden air from the centrifuge room (Fig. 7) was permitted to discharge to the atmosphere through open doors and windows. Later the room was closed to the atmosphere, and air from the room was exhausted through hoods above the centrifuges. The exhausted air passed through a boric acid scrubber which, as indicated earlier, failed to remove the odors.

At the present time, air is exhausted from the closed centrifuge room, through the same centrifuge hoods (Fig. 8), by means of an exhaust fan. This air is then passed through a sealed duct to a stainless steel tank located adjacent to the one servicing the spray tower. The odor laden air is scrubbed in the duct by sulfuric acid mist in exactly the same manner as described for the spray tower. All other control provisions described for the spray tower system apply here, as well, with one addition. Because of the high temperatures used in the soapmaking process and the high humidity in the closed centrifuge room, air conditioners were installed to prevent workers from becoming overheated.

Results

The above described control systems have resulted in relatively odorless conditions in the neighborhood of the plant for several months. There were two brief breakdowns both based on the extremely cold weather experienced. The company has taken steps to prevent recurrence of these breakdowns under similar or even more extreme weather conditions. With these exceptions, one could drive by or walk around the plant detecting any fishy odor. And, except for the brief breakdowns, no odor complaints have been received from area residents.

Conclusions

Control of odors has always been one of the most difficult problems which confront air pollution engineers. In most cases, and this one was no exception, the concentration of the gas or vapor responsible for the odor is quite low. Even so, the odor impact may be considerable, and the cost of removing a few parts per billion can be formidable.

Quite fundamental to the solution of any such problem is identification of the odorant. In this case, amines were indicated both by odor identification and by chemical examination of air samples. Odor identification assisted greatly in selection of suitable sampling equipment and sampling media.

Selection of proper control equipment follows identification of the odorant. Usually a number of control methods are suitable. In this instance, the types of control considered were adsorption on activated charcoal, oxidation by chlo-

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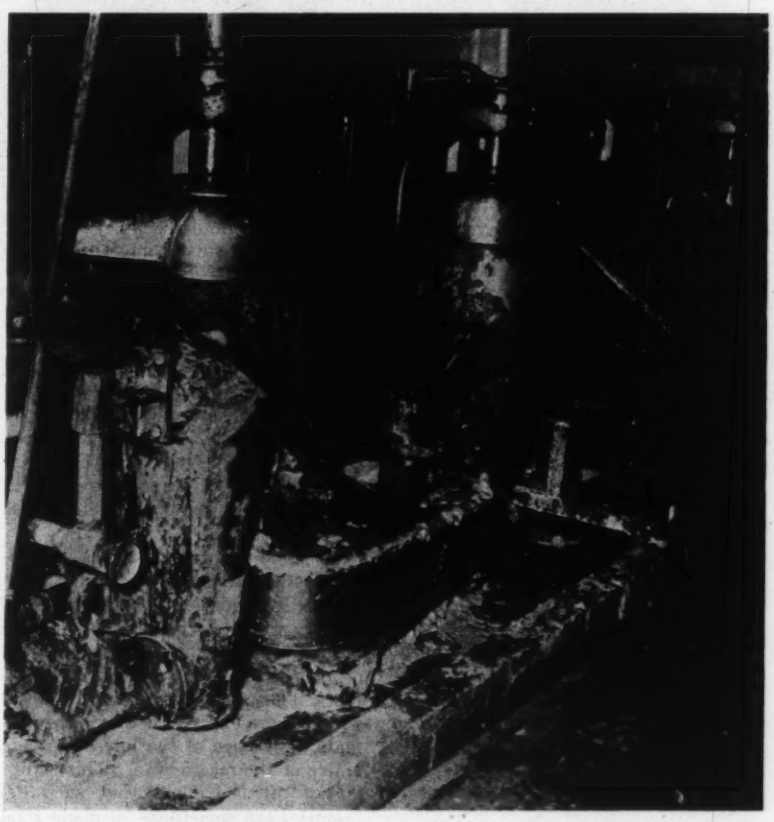

Fig. 7. Two pairs of high speed centrifuges in centrifuge room. Partial view of exhaust hood above far pair.

Planning an ENVIRONMENTAL SURVEY *for a Nuclear Power Plant Site*[*]

PETER J. BARRY, Environmental Research Branch, Atomic Energy of Canada Ltd., Chalk River, Ont., Can.

Probably more effort has been put into safety in the nuclear industry than in any other at such an early stage in its development. Attention is paid to the safety not only of workers within the establishments but also of the population in the neighboring areas. An environmental survey is the first step required to protect the public from any possible consequences of operating a nuclear power plant.

Health becomes endangered when the body is exposed to the ionizing radiation emitted by radioactive materials. The radiation may be from external sources or from sources which are deposited inside the body; which have entered by inhalation of contaminated air, ingestion of contaminated food or water and, to a lesser extent, deposition in open wounds. The survey therefore consists of sampling and assaying the resources of the area, e.g., air, water, and foodstuffs, to ensure that no such contamination exists.

Although an infinite number of samples may be taken, it is possible only to handle a limited number. The survey requires careful planning so that adequate coverage is obtained with minimum effort. This paper describes some of the most important factors that should be considered when planning an environmental survey.

General Considerations

The release of radioactive material may occur during an accident when control of the reactor is partially or completely lost. It is not the primary purpose of the survey to detect such accidents but it would be of great value in the subsequent evaluation of the consequences. The release of active material is more likely to be chronic than acute and to involve only small quantities. The escapes may result from a minor failure of reactor operation to meet design specifications, or they may be planned as the deliberate release of wastes whose storage is not economically feasible.

The degree of safety or hazard associated with these occurrences depends on the dispersive properties of the environment which dilute the materials to innocuous concentrations. While the environment has an almost unlimited potential for absorbing "foreign" matter there is sometimes an inconvenient delay before this is achieved. Furthermore the material may follow tortuous and perhaps unpredictable paths during the process. Living organisms complicate the picture by concentrating radioactive waste products within their bodies which later enter food chains and, ultimately, may reach the human population. The environmental survey must recognize these vagaries of dispersion since they complicate a sampling program of limited scope. Care must be taken in deciding what samples should be taken and where they should be taken, so that radioactive material does not escape detection and hazardous conditions do not arise in places where they would not normally be expected. The means by which these difficulties are overcome will be discussed in more detail in a later section.

It should be apparent that a well designed environmental survey is the result of close co-operation between specialists from various disciplines. These will normally include hydrologists, meteorologists, ecologists, chemists, and physicists. The efforts of these specialists will be more effective if they have intimate knowledge of the forces that are active at the reactor site. This luxury is not often available but such deficiencies can sometimes be made good by enlisting the help of various government agencies that normally work in the area concerned. One should not forget the essentially experimental nature of the environmental survey which, apart from its intrinsic purpose, should also be capable of increasing our understanding of the behavior of dispersive agencies.

Transport and Dispersion Mechanisms

Transport of radioactive material from the reactor to the human population depends on the movement of air and water.

Diffusion of the material throughout the environment is effected by turbulent components within the motion of the transporting fluid. Thus effluents discharged into slowly flowing water or stable air will become diluted very much more slowly than those discharged into a turbulent fluid. Whether or not the health of the general public will be affected by these discharges depends on the amount of toxic material involved, the rate of discharge, the volume available for dilution, and the rate of dilution within the volume.

The characteristic properties of air and water with respect to these variables will now be considered.

Water

The behavior of effluents discharged into water depends on the location of the discharge. If it is into ground water, the subsequent behavior of the radioactive material depends on the chemical state of the nuclides present, the nature of the soil and the rate of ground water movement. In general the dispersal of this type of discharge is subject to considerable delay, a fact utilized at several reactor facilities in the disposal of low-level liquid waste. The rate of movement of the waste is studied by sinking wells and assaying the samples of soil and ground water from various

[*] Presented at the 53rd Annual Meeting of APCA May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

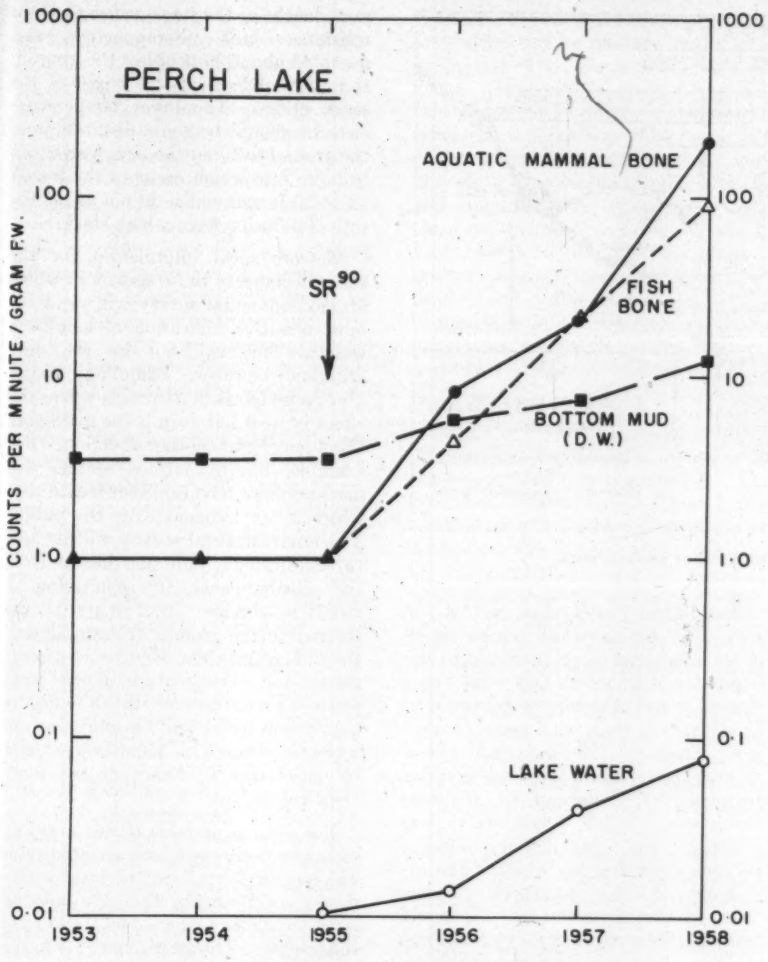

Fig. 1. The distribution of radioactivity in Perch Lake.

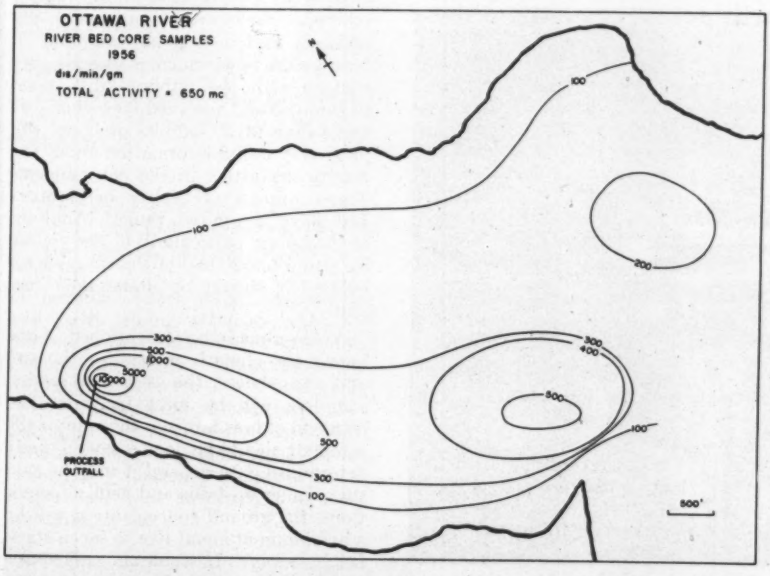

Fig. 2. The pattern of fission products from the Chalk River Project deposited on the bottom of the Ottawa River. Results of 1956 core samples.

depths. The safety of the operation depends on there being a restricted drainage pattern and control over the usage of the plants growing in the path of the waste and of the animals feeding on those plants. The ground water will eventually discharge into a free-flowing drainage system involving lakes, rivers, and eventually the open sea.

Dilution of wastes discharged into open water depends on the turbulence of the flow. The distribution of the waste will often be difficult to predict and sampling of the water is attended with some uncertainty. General sampling, intended to give results representative of the whole mass of water, should be done some distance downstream where it can be reasonably certain that dispersion throughout the total volume has been attained. However, intakes for town water supplies should be regularly sampled to determine the fitness of the water for human use.

In general, sampling of the water itself is not a satisfactory means of determining the radioactive burden of the river or lake as a whole.

A high proportion of the radionuclides discharged into surface waters either became concentrated within the bodies of living organisms or, entering the complex chemical processes in the water, are deposited on the bottom as sediment (Fig. 1). Analysis of the bottom sediment gives useful information about the long-term trends in the river as well as some idea of paths followed by the wastes where they are carried by currents. At Chalk River, numerous analyses of the bottom sediments from the Ottawa River have been collected and show a very interesting deposition picture (Fig. 2).

However the results obtained have to be interpreted with care. For example, at Chalk River it has been found that the relative proportions of radionuclides present in bottom sediments are different from those proportions present in the outflow. For example the relative abundance of cesium-137 in the sediment is very much lower than that in the outflow. The rate of concentration of radionuclides by fish is not constant but follows the seasonal metabolic cycle which in turn is controlled at least in part by temperature changes. Complex relationships exist between living organisms and their environment and the services of an experienced biologist are essential. More detailed summaries of Chalk River experience in monitoring liquid-borne wastes have recently been published.[1]

Air

The motions of the atmosphere present similar problems. The frequent occurrence of smog in urban areas testifies to the slowness with which the

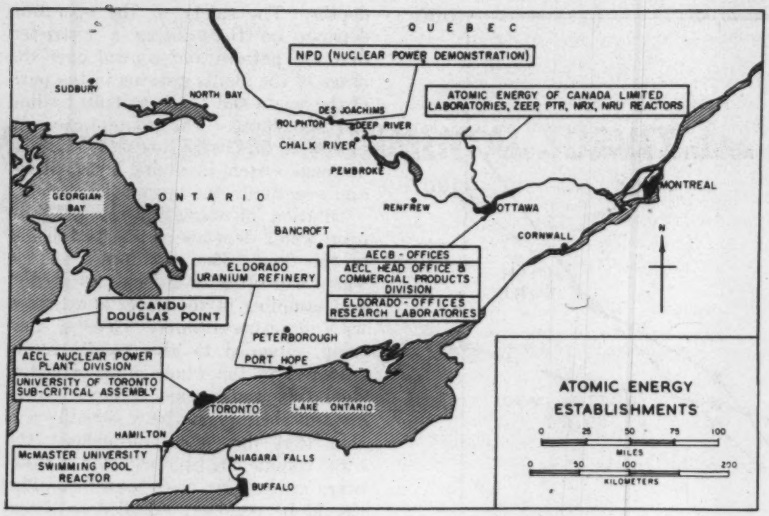

Fig. 3. Location of Canadian atomic energy establishments.

atmosphere will sometimes accept waste injected into it. Airborne wastes can affect the human population directly through gamma radiation from the passing cloud or by deposition in the body after inhalation. Particulate wastes and some chemically active radionuclides became deposited on the ground or absorbed by grass and foliage and subsequently enter food chains that end with man.

The direction taken by airborne material depends on the wind direction, and the rate of dilution depends on the speed of the wind and the stability of the atmosphere. The long-term pattern of contamination resulting from the reactor discharge are determined by the climatological modes that exist at the site. The time-average concentration in air at a point is proportional to the frequency with which the wind blows toward it and inversely proportional to the harmonic mean wind speed for that wind direction. The important climatological parameter is the wind-direction frequency (f_i) weighted by the harmonic-mean wind speed (u_i). Experience reveals two distinct diffusion regimes depending on whether the atmosphere is stable or unstable. So the value of the parameter (f_i/u_i) should be evaluated separately for each of these regimes. The minimum meteorological equipment should include a simple recording anemometer mounted at the same height as the stack orifice and two resistance bulb thermometers, one mounted about 30 ft above the ground, the other at least at the height of the stack orifice. The lower temperature element should be some distance from the ground to avoid the large variations in lapse rate which occur in the lowest 10 to 20 ft and which do not affect the rate of diffusion from a high stack.

Meteorological information for the site will indicate those sectors in which an environmental survey will yield the most sensitive indication of long-term trends. This will not be the only criterion however. Sampling should also be undertaken at points where the effect is most felt even if the maximum effect may lie in another direction. For example, heavily farmed sectors will demand more attention than waste land which is not frequented by the public. The environmental survey will include (*a*) monitoring of radiation dosages from the passing cloud, (*b*) monitoring of radiation dosages from material deposited on the ground, (*c*) sampling of the animal and plant populations around the reactor. Frequent sampling of farm produce should be undertaken to ensure that it is fit for human consumption and a system of biological monitoring should be undertaken to determine any long-term trends.

The decision whether or not to set up radiation dosimeters around the reactor will largely depend on the local conditions; for example, the proximity to large numbers of people and the type of the reactor. The measurement of radiation dose due to ground deposition of radionuclides requires the use of motor vehicles or aircraft in order that the large areas involved can be adequately covered. Biological monitoring will certainly include regular sampling of farm products which come directly into contact with the public. Milk must be sampled and analyzed for cesium-137 and iodine-131. Rabbits or hares will yield very useful information about the rate of deposition in the environment. These animals are solely herbivorous and have a limited range. Analyses of the bones, particularly of the young, for strontium-90 and of the thyroids for iodine-131 should be undertaken regularly.

As has already been mentioned, if one knows the climatic modes for the site one can choose the sector in which sampling will be most fruitful. The question of how far from the reactor the sampling should be done is not so easily determined. In general it may be said that, under unstable and neutral conditions, the ground concentration will be a maximum at about five to seven stack heights away. In stable air, radioactive clouds may travel much greater distances without appreciable dilution

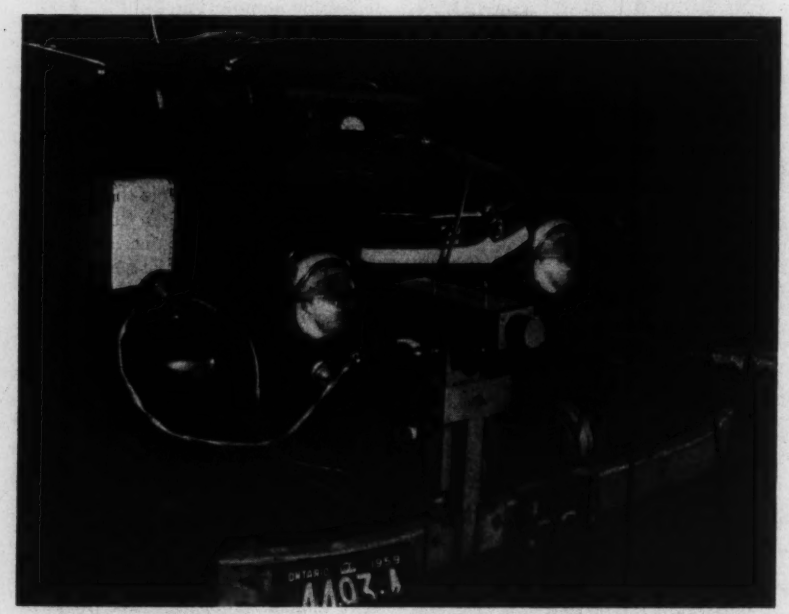

Fig. 4. A survey vehicle with the gamma counter attached. During operation the recorder and meter are carried in the cab of the vehicle.

and without reaching the ground. Rain will bring some of the iodines and particulates to the ground but the morning fumigation will usually be the chief agency—other than orographic intersection. There will probably be an outer zone where ground-level concentrations will be higher than in the intervening space. The inner zone can be defined by existing diffusion equations while the outer zone will be somewhat diffuse and located with some difficulty. The inner zone will usually be located within the restricted property, while the outer zone, being generally outside this area, is of much importance and some estimate of it should be attempted.

One approach is to consider the occurrence of the parameter (ut) where u is the average wind speed during an inversion and t is the time of persistence of the inversion. If topographical features of the area permit the inversion to persist for distances of 20 to 30 mi away then a well-defined mode in the frequency distribution of the parameter would satisfactorily define the center of the outer zone.

The climatological data should also be studied to determine any pronounced seasonal variation in the climatic modes. If these occur then changes in the regional distribution of effort might be applied at the appropriate times. This would be particularly important if they coincided with seasonal changes in population density, economic activity, or amenity usage in the area. At the CANDU site on Lake Huron, for example, there is a heavy tourist industry, the main influx of population being largely concentrated two miles to the south of the reactor in a provincial park which last summer was visited by over 100,000 people.

Organization

The organization of the environmental survey may be conveniently considered in three phases.

Phase I

This begins when the site has been selected. As much information relevant to the site as possible is collected. Population densities, type and extent of farming, water usage, commercial and sport fishing activities, etc., are studied so that the plans for the survey can be formulated. Meteorological information is collected or if none is available measurements should be undertaken. Water resources will be studied including currents, flows, and thermal properties. Liaison is established with federal and local government agencies operating in the area.

Phase II

This is the preoperational phase. Sampling and analysis will be started to determine the natural background of the area which will be the base line for later evaluation of the effects of reactor operations. It should be remembered that this phase of the survey can never be repeated; it should therefore be as complete as possible. Subsequent work may show that some sampling stations and operations are unnecessary and these can then be abandoned. Phase II should begin at least one year ahead of reactor start-up and preferably two years ahead. This enables the natural background to be determined over a variety of conditions so that natural seasonal variation can be estimated.

Phase III

Phase III is the continuing sampling program and it commences immediately the reactor becomes operational. The procedures drawn up in Phase I and tested during Phase II will be carried on routinely. However, careful scrutiny of the results obtained is essential. Redundant procedures should be eliminated. During this phase it is to be expected that equipment and techniques will be improved. However, these should be incorporated into the routine survey only after careful consideration as to how they will affect the comparison of new results with those obtained in Phase II. When instrument constants are changed the new instrument should be carefully compared with the existing instruments so that corrections can be made. There is considerable advantage in retaining samples collected in Phase II so that they can be assayed later using the new techniques. If bomb tests are started again a lot of the background work done in Phase II will be useless. For this reason there should be an area chosen that is well away from possible contamination by the reactor operations so that changes due to further bombs tests can be evaluated.

NPD 2 Environmental Survey

The NPD 2 (Nuclear Power Demonstration) is being built on the Ottawa River 15 mi upstream from the Chalk River installation (Fig. 3). The site lies in a valley running NW to SE. The northern bank of the river rises sharply to heights varying from 350 to 850 ft while the southern bank rises gently and evenly to a height of about 350 ft. The predominant NW and SE winds are channeled by the valley.

The solid- and liquid-waste disposal program will be carried out at the Chalk River disposal area. The principal contamination of the environment if any, would therefore be due to airborne wastes emitted from the 180-ft stack.

Forest and lakes occupy most of the 315 mi² in a 10-mi radius around the site and most of the area is inaccessible. A provincial highway parallels the river, and an Ontario Hydro Electric Power Commission service road serves the area on the Ontario side to the South West, and a lumber trail across the river serves the area to the North. The total human population is about 5000 which is mostly concentrated in small towns along the provincial highway. Only 1.5% of the area is cleared land and about half of the cleared areas are abandoned farms. Some of the farm land still being worked supports small herds of dairy cattle, but the total bovine population amounts to less than 100 cows. The forested areas are lumbered and the surface waters used for drinking and cooking, while deer, grouse, rabbits and fish are sometimes taken for food. The area is popular among sportsmen who come to fish and hunt in season. Isolated bathing beaches are used along the Ottawa River. Just outside the 10-mi radius is the downstream town of Deep River which has a population of about 4000 and takes its water supplies from the

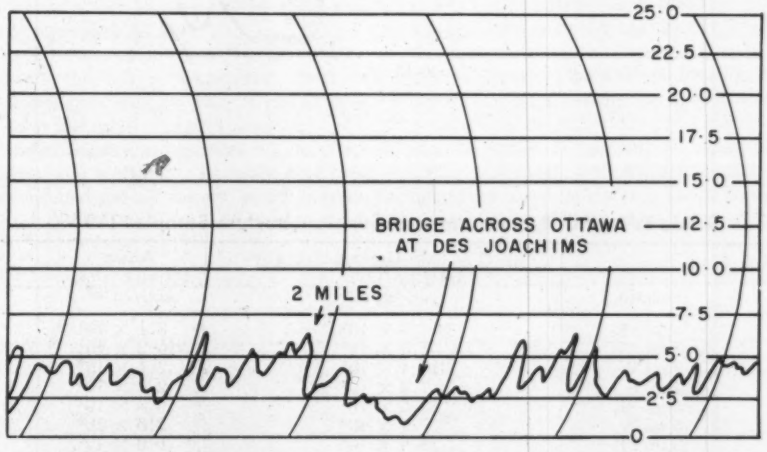

Fig. 5. A portion of the gamma survey chart. (Instrument scale—25 microroentgens; time constant—2 secs; vehicle speed—10 mph).

Table I—NPD-2 Environmental Survey—Waters (1959)

Type	Number	Range of Beta-Gamma Activity in $\mu\mu$C/l[a]	Range of Alpha Activity in $\mu\mu$C/l[b]
Ottawa R.[c]	7	8.4–32.1 (June) 6.6–22.2 (December)	0.05–0.11 (Dec.)
Lakes	6	17.7–51.0 (June) 8.4–14.7 (December)	0.06–0.17 (Dec.)
Wells	2	2.4– 3.3 (June) 1.5– 2.7 (December)	0.04–0.62 (Dec.)

[a] Based on efficiency of counter for K-40.
[b] Based on efficiency of counter for natural uranium.
[c] Radiochemical analysis of Ottawa River water (1959): Sr-90, 0.84–1.02 $\mu\mu$C/1; Sr-89, 0.10–0.18 $\mu\mu$C/1; Cs-137, 0.23–0.25 $\mu\mu$C/1.

Table II—NPD-2 Environmental Survey—Snowshoe Rabbits (1958)

Location	No. of Specimens	Tissue	Range of Beta-Gamma Activity, $\mu\mu$C/g FW[a]
Site	3	Flesh	4.5–15.6
		Bone	15.9–23.8
		Liver	8.3–11.8
2 mi E	2	Flesh	7.3–11.8
		Bone	31.8–34.3
		Liver	7.0–10.2
2 mi W	2	Flesh	5.7–13.4
		Bone	24.0–30.9
		Liver	8.5– 9.5
$1^1/_2$ mi SW	1	Flesh	10.8
		Bone	28.0
		Liver	12.1

[a] Based on efficiency of counter for K-40.

Table III—NPD-2 Environmental Survey—Ottawa River Fish (1959)

Location	No. of Specimens	Tissue	Range of Beta-Gamma Activity, $\mu\mu$C/g FW[a]
Site	15	Flesh	2.2–12.0
		Bone	1.8–10.8
		Stomach	0.0– 5.4
6 mi downstream	20	Flesh	2.7– 7.5
		Bone	0.7– 5.7
		Stomach	0.9– 6.3
12-mi downstream	22	Flesh	1.8–10.4
		Bone	1.4–15.6
		Stomach	1.8–10.7

[a] Based on efficiency of counter for K-40.

Table IV—NPD-2 Environmental Survey—Pasture Samples (1959)

Location	Beta-Gamma Activity (Oct.), $\mu\mu$C/sq m[a]	Alpha Activity (Oct.), $\mu\mu$C/sq m[b]
1 mi SE	13.3×10^3	3.1×10^2
1 mi SW	57.0×10^3	15.2×10^2
2 mi W	10.4×10^3	2.1×10^2
4 mi S	7.2×10^3	2.4×10^2
5 mi SE	13.5×10^3	6.3×10^2
5 mi W	7.1×10^3	2.6×10^2
9 mi SE	16.6×10^3	6.0×10^2

[a] Based on efficiency of counter for K-40.
[b] Based on efficiency of counter for natural uranium.

river.

The preoperational area survey was started toward the end of 1958. Since the reactor will not be operational until 1961 this will provide data for over two years.

1 Monitoring for airborne radiation sources. This will be provided by four recording dosimeters located around the reactor. Two will be situated in the valley, one upstream and the other downstream of the reactor at the edge of the restricted property. A third is situated south of the stack on the edge of the provincial highway and the fourth in the village of Rolphton to the West. The meters[2] are battery-powdered and the detectors are halogen-filled geiger tubes with suitable absorbers to give an energy-independent response down to 80 kvs. The amplified pulses are recorded on a 1-mA full scale clockwork recorder. The response is logarithmic giving a range of doses from 10 uR/h to 10 mR/h.

2 Radiation monitoring for ground-deposited sources. This requires the use of a detector mounted on a motor vehicle or aircraft in order to cover the large areas involved. Such a detector should be rugged and reliable, it should be portable so that fields away from the vehicle and roads can be measured, it should give a permanent record and have a wide range of sensitivity so that it can both detect small increases in background and also be useful after accidents. Such an instrument has been built by the Radiation Dosimetry Branch[3] for use at NPD-2 (Fig. 4). It utilizes an anthracene crystal detector and photomultiplier, the pulses from which are amplified and fed to a count-rate circuit. Two ranges are provided, 25 uR/h and 100 uR/h full scale, with a choice of two time constants two sec for use while moving and 20 sec for use in the stationary position. A recorder is housed in the cab of the truck and land marks can be noted on the chart (Fig. 5). The vehicle is driven at 10 mph. Experiments are being carried out in co-operation with the Canadian Army Air Observation Flight so that an aircraft-mounted instrument can be used. There are several difficulties associated with this; one is tracking the aircraft flight path and another is knowing the altitude above the ground. Experiments using a long-range radar tracking device are now in progress.

3 Water survey. Fifteen water-sampling stations have been set up in the survey area. Seven of these are on the Ottawa River including two municipal water intakes. Two others are at wells used for domestic water and the remainder are at accessible lakes. Three fish-sampling stations have been set up on the Ottawa River at 0, 6, and 12 miles downstream. Bottom sediments have also been collected at these stations.

4 Land survey. The land survey has

(*Continued on p. 48*)

A New GAS-LIQUID INTERPHASE REACTOR*
Applied to Air Pollution Control†

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Over the years a considerable art has developed in gas-liquid contact devices for chemical processing. The literature contains theory and data directed primarily toward specific major applications. Some applications have advanced from the status of an art to the area of numerical certainty characteristic of applied science. In such applications, engineering design can be sufficiently precise to permit the construction of a plant which will fully meet production objectives.

In general the technology of gas-liquid contact devices or scrubbers applied to the air pollution control field has not reached this degree of maturity. Problems are so varied in type of contamination and in order of physical size that the specific engineering approach available for major chemical operations is not economically feasible. Consequently, a major advance in gas-liquid contact technology has been in demand, in order to cover the consequent broader margin of uncertainty. To meet this need for a stronger measure of control over many contaminants, the new method of interphase reaction described in this paper was developed.

Present Systems

Present methods of gas scrubbing by a liquid, or for the purpose of this paper air scrubbing by water, usually fall into one of the following subdivisions:

1 Passing air through a chamber in which water is violently agitated by mechanical means.
2 Passing air through a chamber which is filled with a spray of liquid emanating from nozzles.
3 Setting up a succession of waterfalls or sheets of water through which air must find its way.
4 Causing air to flow upward through a chamber filled with irregular solid shapes over which there is distributed downward flow or trickle of liquid.
5 Forcing of air through a pool of liquid which may be shallow or deep depending on design.
6 Venturi contact in which either the gas or the liquid may be the driven fluid.
7 Wetted fabrics and structures of fiber.
8 Impingement of air on a film of water.

A New Principle

After some years of field trials it is now possible to disclose a new class of equipment for interphase reaction based on balanced countercurrent flow of gas and liquid in a horizontal flooded bed. Liquid is present in the interstices of the packing as a physically continuous phase in generally downward gravitational flow. The gas rises through the bed as a discontinuous phase consisting of separated bubbles.

The operation of a flooded bed as seen through a transparent wall is deceptively simple, but in reality this new technique is quite complex. The implications and practical results, however, are startling. In contrast to conventional packed towers, which become inoperative and lose efficiency when flooded, the wet beds of this method are operative only when flooded. In contrast to the height of conventional towers scrubbers designed to operate on this basis are tiny in height. The following is intended to identify practice with basic concepts of this interphase action.

Practical Equipment

Figure 1 shows a small industrial unit. Figure 2 and Table I show overall dimensions and other related information for a range of laboratory and small industrial units including the 2000 cfm unit of Fig. 1.

Figure 3 is a phantom front elevation in partial section of the unit of this series rated at 1000 cfm. Structurally, the unit consists of the air chamber shell and a platform for the fan, motor, and drive joined together on a common base. The air chamber is subdivided into three plenums by two horizontal beds of aggregate. External connections consist of inlet and discharge ducts, liquid supply and drain lines, and the electric power line. The rotating parts of the assembly are isolated vibrationally from the main structure. Fundamental instrumentation consists of a liquid manometer to measure the hydrostatic pressure across each bed, and a rotameter or other instrument to measure liquid flow rate. Supplemental instrumentation may be applied to air flow, temperatures, pH values, and so on.

Table I—Dimensional Data

Cfm	Inches a	b	c	Motor, hp	Erected Wt, lb
25	8	30	15	1/4	100
50	11	30	20	1/3	200
100	15	33	26	3/4	400
200	20	38	36	1 1/2	900
500	30	58	60	2	1750
1000	46	60	75	5	2700
2000	63	63	102	7 1/2	5000

* Patents pending.
† Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

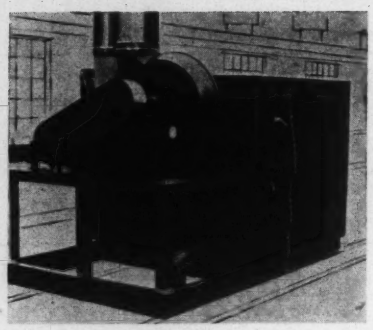

Fig. 1. Small industrial air cleaner rated at 2000 cfm and 12-in. water head.

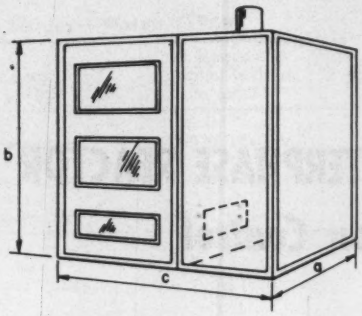

Fig. 2. Style and over-all dimensions of one series of small industrial units.

The Method of Operation

In normal operation water or other liquid is introduced through a multiplicity of nozzles above the top of the upper bed. Liquid flows downward through the two beds in succession against a rising flow of air which enters below the first bed and is exhausted from the upper plenum into the fan and discharged. Air rising through the bed delays the liquid in the interstices of the packing causing the entire depth of the packing to be flooded within the confining dimensions of the bed. Hence the only method of passage for the air from the lower plenum to the top plenum is to bubble through the interstices of the lower bed, recombine in the middle plenum, and finally bubble through the upper bed on its way to the upper plenum and the fan.

Figure 4 is an enlarged section of a portion of a flooded bed. It is a picture representing an instantaneous condition of countercurrent flow. The shaded areas represent pieces of packing, the white areas are bubbles, and the dark areas represent the flooding liquid.

The small quantity of air contained in a bubble formed as it enters the lower surface of one of the beds must start to rise through one of the tortuous paths available for its upward passage. The bubble undergoes many changes in cross section, incessant impingement at successive angular deviations in its path, frequent subdivision, and intermingling with other bubbles also rising in turbulent divisive surges. Each bubble or sac of air in its rise must also displace liquid vertically or horizontally. In the meantime there is a general downward flow of the total water charge held in the packing depending upon the rate of new water supply at the top. The liquid and gas phases are in countercurrent flow and within the outline dimensions of the packing which is a solid phase. The interplay maintains a maximum fresh interphase area and spontaneous volumetric contact between the gas and liquid phases. Time required for intraphase diffusion therefore is reduced and has a minimal adverse affect on contact efficiency.

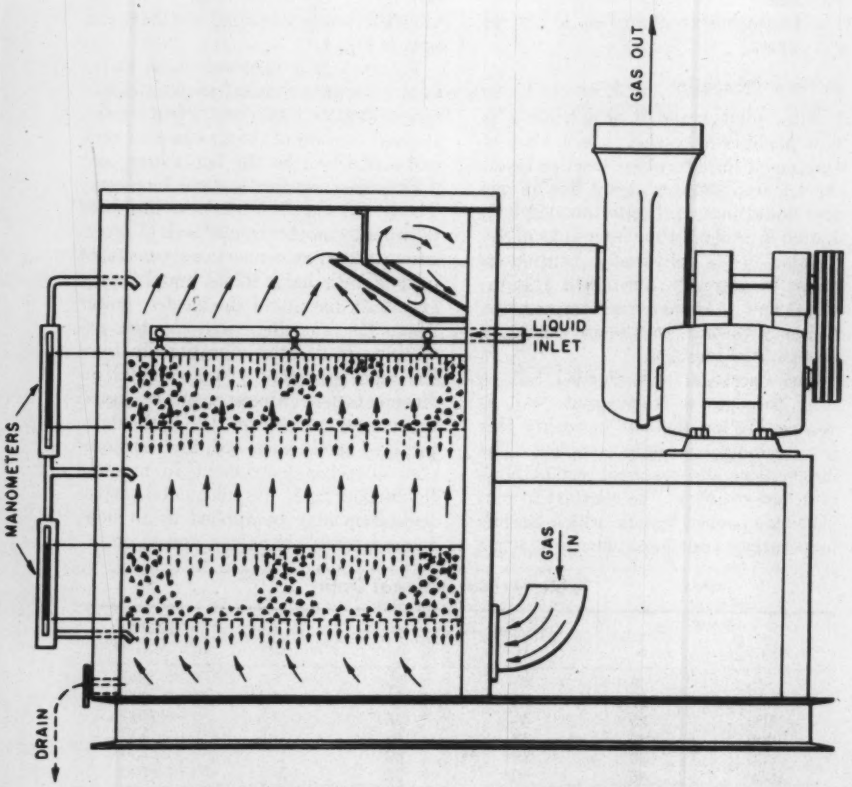

Fig. 3. Phantom elevation of 1000 cfm unit rated at 12-in. water head.

Ideal Operation of Interphase Reactor

In the ideal operation of the interphase reactor, the depth of liquid begins at the supporting screen and extends through the full depth of the packing from the screen to the upper surface but no further. The operation of the scrubber is said to be in full balance when steady-state countercurrent flow of the gas and liquid maintains the full depth of liquid in the packing.

Under these conditions a manometer reading across the bed will show a hydrostatic head approximately equal to the depth of the packing. For practical purposes the manometer readings have great significance in monitoring scrubber performance. Parallel manometers can be installed at remote observation points.

Operation of a bed at less than full balance utilizes less than full contact capacity. Operation with the liquid level above the top surface of the bed results in abnormal pressure drop, and lower mechanical efficiency at no appreciable advantage in contact effectiveness. Practical means are employed to regulate the balance at any desired value, but these are not intended to be within the scope of this presentation.

Characteristic Numerical Factors

Since air can pass through a reaction bed only in the form of irregular sacs or bubbles completely surrounded by liquid, it is useful to establish a geometric concept of developed interphase surface area. The observed form of bubbles is either flat or elongated and it is appropriate to examine the magnitude of surface increase of a volume of gas as it is flattened or elongated. Figure 5 with Table II shows the effect of flattening a cubic foot of gas to a thickness h or of

Table II

h or d in Inches	Area of Opposite Surfaces of 1 Cubic Foot Compressed to Thickness "h"; Surface of Flat Bubble in Ft^2	Cylindrical Area of 1 Cubic Foot Elongated to Diameter "d"; Surface of Cylindrical Bubble in Ft^2
12	2	4
6	4	8
2	12	24
1	24	48
1/2	48	96
1/4	96	192
1/8	192	384
1/16	384	768
1/32	768	1536

elongating it in cylindrical form to correspond to a diameter d.

Plaster casts taken of interstices in actual aggregate used for packing shows a preponderance of dimensions below one-eighth of an inch. Therefore, the minimum surface area must be no less than 200 ft^2 on the basis of the dimensional consideration alone. In Figure 5 on the other hand, the edge or end areas are neglected because they are negligible for small values of d or h. In the real case, however, the edge or end areas are a large addition to the total area. Moreover each bubble is reshaped and participates in many interchanges in passing through a few inches of a flooded bed. It is reasonable to expect that the actual effective area for a cubic foot of gas passing through the bed is large in terms of the areas expressed in Table II.

Relative air and water rates are key engineering factors in scrubber applications. Air and water rates on a weight basis are important in transfer calculations involving either heat or contamination. On an equal weight basis at 60°F a scrubber must establish contact between 817 vol of air (dry basis) to a single volume of water. At 75°F the ratio is 839. Because of this great disparity in relative volumes of gas and liquid it can be seen that the storage of liquid in a flooded bed has great physical significance in the generation of gas-liquid contact surface area.

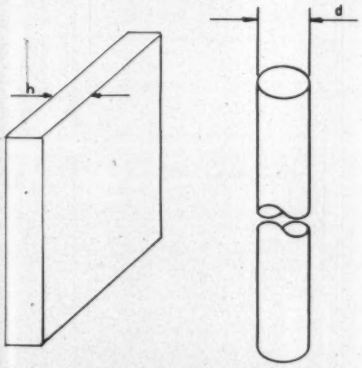

Fig. 5. Examples of increasing area when a cubic foot of air is flattened to thickness of h in. or elongated into cylindrical form with diameter of d in.

Table III shows a set of values of air in cubic feet per minute for a range of scrubber sizes, the equivalent pounds per hour at 60° and 75°F and the equivalent weight of water expressed in gallons.

Moisture Content of Discharged Air

Air, on entering the first reaction bed flooded with water, quickly adjusts to the temperature of the water and to 100% relative humidity at that temperature. Further humidity and temperature adjustments may occur in passage through successive beds if temperature differences exist. The condition leaving the last bed plus any slight droplet or fog carryover will determine the moisture content of the discharged air stream. Droplet or fog content, is at a minimum because the water phase in the beds is continuous rather than in the form of a fog, mist, or spray. Any wetness in the air stream entering the fan may be reduced or eliminated by suitable mist or fog eliminators before the fan intake. The bulk of the mechanical energy of the fan is ultimately converted as temperature rise to the thermal energy of the discharged air. This shows usually in the absence of visible mist discharge except in exceptionally cold weather.

Discussion of Pressure Drop

The word plenum as applied to the

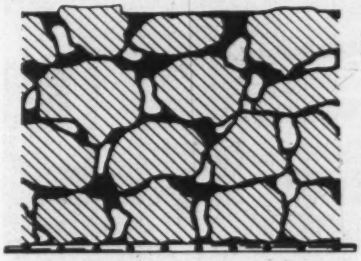

Fig. 4. Pictorial representation of flooded bed showing instantaneous position of a group of bubbles rising through liquid in interstices of packing.

open air space in the air chamber connotes the presence of a pressure differential. In the instance of the number one or entry plenum, the available pressure relative to the next plenum supports the liquid in the first reaction bed in the process of maintaining upward flow of air through the flooded interstices of the packing. Each successive plenum similarly supplies air to the next reaction bed up to the last or discharge plenum which supplies the air to the pre-fan mist collection system and the fan itself.

The pressure differential across the reaction beds maintains the turbulent upward flow of the discontinuous sacs of the gas phase. The quality and violence of this action both causes impingement and causes molecular diffusion through the gas phase in exposing the entire volume of gas to the surrounding liquid surface. The collateral horizontal agitation of the liquid similarly results in extremely rapid dispersion of captured contamination away from the initial liquid contact surface into the general volume of the liquid. This horizontal agitation or pumping of the liquid phase also is utilized to effect wide distribution of the liquid delivered to sections of the bed whether in the form of many small streams or in the form of a relatively small number of larger streams. It is a corollary that this action likewise controls localized differences in liquid temperature or contamination which might otherwise result from local-

Table III—Reference Values of Relative Air and Water Rates

	60°F			75°F		
Cu Ft Air/Min	Lb of Air/Hr	Equal Wt of Water in Gal/Hr	Equal Wt of Water in Gal/Min	Lb of Air/Hr	Equal Wt of Water in Gal/Hr	Equal Wt of Water in Gal/Min
25	113	13.5	0.23	108	13.0	0.22
50	225	27	0.45	216	26.0	0.43
100	450	54	0.90	432	51.9	0.87
250	1,125	135	2.25	1,080	130	2.17
500	2,250	270	4.5	2,160	260	4.34
1,000	4,500	540	9.0	4,320	520	8.68
2,000	9,000	1,080	18.0	8,640	1,040	17.3
3,000	13,500	1,620	27.0	12,960	1,558	26.0
4,000	18,000	2,160	36.0	17,280	2,080	34.6
5,000	22,500	2,700	45.0	21,600	2,600	43.4
50,000	225,000	27,000	450.0	216,000	26,000	434.0

Fig. 6. A small industrial package unit with standby fan for continuous operation on vapors of hydrogen chloride.

ized channeling caused by random variation in the geometry of the packing.

Commercial Trends

Commercial units thus far have tended toward standardization on two beds six in. deep as illustrated by Figure 3. It is a convenient present practice to rate reaction beds at 80 ft/min in terms of an upward gas flow countercurrent to a liquid flow of $^1/_2$ gal/min/ft.^{2} At these values, the water rate on a weight basis is approximately two thirds of the air rate. This rating, however, permits considerable latitude in adjustment of both the gas and liquid rates. It has been established, for example, that units designed for this rating will permit flow rates at least 50% higher for the gas and by choice of packing or by other means the liquid flow rate may be regulated to a fraction of the rating or a multiple of several times the rated value. These values are indicative of the great latitude available for further development of designs.

Economy of liquid, particularly if it is water with chemical additives or if it is a more expensive chemical liquid may dictate collection in a sump and a recirculating pump. Sedimentation, filtration, and control of temperature or chemical content may for example be incorporated in such an installation. In the case of abundant supply of fresh low cost water, recirculation may not be important, but increasing attention will be given to recirculation in the face of increasing demands for water economy and for control of water pollution.

Fig. 8. A unit rated at 1000 cfm and housed for complete protection against outdoor exposure.

Units having up to five packed beds have been used, but experience in applications so far has encouraged limitation to two beds for systems requiring a single liquid. Successive washes through different liquids can be provided by recirculating a different liquid through each one of several beds which are hydraulically independent.

Installations are made indoors and outdoors. Indoor applications of relatively small units are particularly feasible because of the compactness and cleanliness of the units and the great benefit of proximity to the operation involved.

Large installations in themselves will be substantial or major structures and economy will largely dictate outdoor installation. Such units, field erected in place, are custom engineered for each application and may have a variety of horizontal shapes depending upon available space.

The present design program includes capacities exceeding 30,000 cfm and considerably larger units are contemplated.

Application

Hydrochloric Acid

Figure 6 shows a 2000 cfm unit with dual fans, rated at 12 in. pressure drop installed on a plant roof. Controls and instruments are installed within the plant on the ground floor. Dual fans are provided in this case, one of them as a standby, since the operation is often continuous for several weeks at a time. The unit is operated at 2000 cfm of air with water supplied at 10 gpm and a total pressure drop of 11 in.

In this and other applications for the absorption of vapors of HCl in concentrations up to 10,000 ppm, the major part of the acid is absorbed in the first 2 in. of the lower bed and efficiency to all practical purposes is 100%.

Oxides of Nitrogen

Figure 7 shows a pair of units which were built for installation next to two fume hoods giving off vapors from a production operation in which molybdenum is dissolved in a mixture of nitric and sulfuric acids. The units are rated at 200 cfm and 12 in. pressure drop, but are normally operated at a lower pressure drop, and a water rate of 1.5 gpm.

The fumes from this and similar operations involving nitric acid are predominantly NO_2 and are among the most difficult in industry to control satisfactorily. Using water alone, absorption

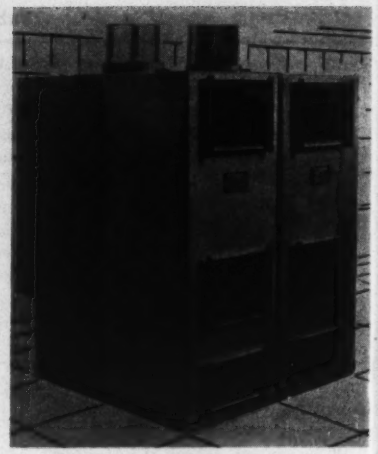

Fig. 7. Twin units, each rated at 200 cfm, for direct absorption of concentrated surges of NO_2 in water.

efficiencies of the order of 80% are obtained with input concentration over 40% or 400,000 ppm.

By the use of two units operating in series, with suitable intermediate time delay for reoxidation of NO, efficiency exceeding 90% has been obtained using water alone as the absorbent.

Vapors from Hot Vegetable Oils, H_2S, Volatile Amines

Figure 8 shows a 1000 cfm unit installed on a plant roof to collect fumes from six process kettles giving off complex fumes including those indicated.

The installation was made at a long established plant in a suburban community. Complaints leading to the installation originated with tenants of a new garden apartment adjacent to the plant site.

The unit operating at eight inch pressure drop with water containing a chemi-

Fig. 9. A portable laboratory hood containing a scrubber based on the new interphase reactor.

cal additive recirculated at six gpm washes out the oil content and absorbs the balance of the offending odors to practical satisfaction.

Removal of SO_2 from Hot Steam

SO_2 fumes coming from a hot vat heated with live steam are the cause of serious complaints in a small city. Steam escaping from the bath carry the SO_2 and because of a liquid disposal problem it is not desirable to collect condensate.

Operation of a 100 cfm pilot unit at 200°F using a solution of sodium carbonate recirculated at one gpm from a sump results in absorption of the SO_2 and discharge of clean steam with a minimum of condensation.

Other Applications

Figure 9 shows a portable laboratory hood containing a scrubber based on the new interphase reactor. This apparatus is dramatic evidence of the radical nature of this development. Only because of the compactness of this new concept is it possible effectively to remove acid and other fumes within the hood structure itself. When it is acceptable to use a unit of this type within air conditioned space without outside exhaust the cost of duct work can be saved and great economy effected in heating and air conditioning costs. The interphase reactor was first developed to make the portable laboratory hoods possible.

In general the interphase reactor is adaptable to gas-liquid-solid contact requirements. It has been used in commercial installations or pilot plant operations for a variety of vapors including acids and alkalies, organic solvents, including alcohol and acetone, dusts including talc, cornstarch and antibiotics, fumes including ammonium chloride, and grinding products, as well as cooking greases and so on. Chemical additions in water greatly increase its scope.

Summary

The following list concisely states some characteristics and advantages available through use of the interphase reactor:

1. Absorption bed only a few inches in depth
2. Mechanical performance fully instrumented
3. All surfaces in beds always wet
4. Dry gas output
5. High efficiency
6. Compactness
7. Low liquid consumption
8. Fully accessible for servicing
9. True portability in small sizes
10. Adaptable to use with existing fume hood installations
11. Effective simultaneously for both dust and vapor absorption
12. Adaptable to air conditioning economy
13. Adaptable to multi-stage chemical processing
14. Blower operates on clean side of scrubber
15. Units can be operated in parallel
16. Operation can be indicated at remote point
17. Effective fire and ignition barrier
18. Latitude in gas and liquid rates
19. Low operating and maintenance cost

Acknowledgment

The contents of this paper are the result of a major and exacting effort dating from 1954. Opportunities for field application occurred in the solution of particularly difficult problems in industry. It is with deep appreciation that I also acknowledge the significant part played by many associates and suppliers.

Applications have been made by the Philco Corp., Bell Telephone Laboratories, Raytheon Manufacturing Corp., Westinghouse Electric Corp., Carter-Bell Manufacturing Corp., and Hamilton Manufacturing Co. Numerical confirmation of efficiencies in absorption of oxides of nitrogen and of sulfur dioxide were made by the John Wood Company, which is the sole licensee under domestic and foreign rights.

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MONITORING SULFUR DIOXIDE with LEAD PEROXIDE CYLINDERS*

FRED W. THOMAS, Division of Health and Safety TVA, Wilson Dam, Ala., and
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One of the problems confronting any incipient or existing air pollution control or study agency is the selection, acquisition, and operation of field instruments. Frequently, accounts are seen of air pollution organizations which, especially at their formation, place great emphasis on complex instrumentation with attendant neglect of personnel requirements and inadequate appraisal of the basic air pollution problems. This is not to infer that no need exists in some situations for the more complex automatic recording instruments required for monitoring oxidants, hydrocarbons, and oxides of nitrogen in large metropolitan and industrial areas.

However, in many areas, especially the coal burning eastern half of the nation, sulfur dioxide continues to be a primary or principal pollutant. Frequently it may also serve as a tracer or index of the more complex pollutants from internal combustion engines and chemical industries. Thomas autometers or other automatic instruments are widely used for monitoring SO_2 where continuous records are needed. However, the initial cost and the cost of operation and reduction and analysis of data limit the use of automatic recording samplers. A less complete measurement of SO_2 exposures may often supplement and conceivably might serve in lieu of recording instruments in some instances.

History of Lead Peroxide Cylinders

This paper is an account of our field experience over a period of about seven years with a simple and economical device for estimating relative sulfur dioxide reactivity or integrated SO_2 exposure at selected sites during time periods of a few days to four months. This device, called variously a lead peroxide wick, candle, cylinder, or instrument, is one of the early air pollution instruments, having been introduced in England by the Building Research Station in 1932.[1] Used extensively in England since that time, only in recent years has it been applied on a significant scale in this country.

Details of the original instrument and developmental investigations are described in a booklet titled "The Investigation of Atmospheric Pollution," Fuel Research Station, 1948.[1] In 1958 Foran, Gibbons, and Wellington[2] published an excellent evaluation of experience with lead peroxide cylinders near Trail, B. C., and other Canadian urban areas. These accounts provide detail information on the construction, preparation, and analysis of lead peroxide cylinders. This discussion relates principally to practical field experiences and uses of lead peroxide data in the Tennessee Valley Authority which may be helpful to others who may also wish to make use of this technique.

Construction, Preparation and Handling

The lead peroxide instrument consists of a 100-cm² strip of sulfur-free gauze fitted around a nonreactive cylindrical holder and coated uniformly with a fresh lead peroxide paste. For protection from mechanical injury and from precipitation, the cylinder is sheltered in a small box with sheet metal top and louvered sides. Details of shelter construction vary and are not believed to be critical. In England porcelain cylinders are used. The U. S. Public Health Service has developed a very good housing employing a polyethylene cylinder. The basic cylinder employed in TVA consists of an ordinary eight-ounce short form glass jar, Fig. 1.

The adaptation developed by TVA may offer some practical advantages especially where transport, shipping, or storage is necessary. Steps involved are:

1 Stapling a 100-cm² band of cotton gauze around a glass cylinder or jar.
2 Painting of gauze strip with uniform coating of 8.0 g of lead peroxide paste.
3 Drying, storage, and preparation for shipment: Freshly coated cylinders are dried overnight in a desiccator and screwed into the smaller of two concentric bradded and soldered metal jar tops. This assembly is then screwed into an open-mouthed 32-oz glass jar. This assembly, Fig. 1, protects the lead peroxide coating from direct

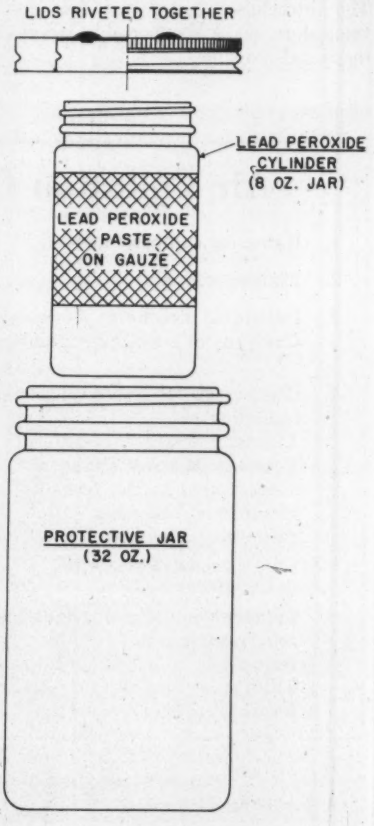

Fig. 1. Lead peroxide cylinder and protective jar.

* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

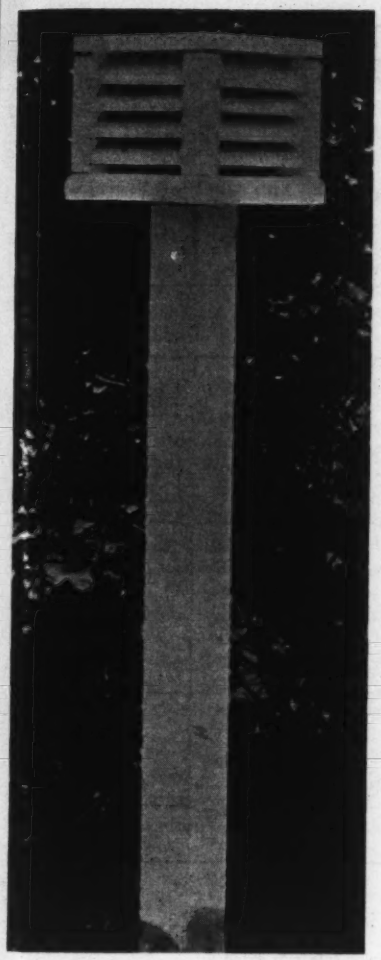

Fig. 2. Louvered field shelter, lead peroxide shelter.

contact with other surfaces, insures against breakage, and prevents exposure of prepared cylinders to contaminated atmospheres before and after field exposure.

4 Fresh cylinder assemblies are fitted into compartmented boxes for shipping or other transport to the field area. At the site of field stations the inner small jar with lead peroxide coating is inverted and screwed into a jar top permanently mounted on the base of the louvered shelter. Exposed cylinders are sealed in the larger holding jar for return to the laboratory. A typical field installation with the shelter mounted on a four-ft post is shown in Fig. 2. In urban areas, other supports such as utility poles may be preferable.

Reaction and Environmental Effects

It is doubtful that the mechanisms of the reaction of solid lead peroxide and sulfur oxides are fully understood. However, investigations of the Fuel Research Station indicated (1) that SO_2 reacts with PbO_2 to form $PbSO_4$ at a "convenient and uniform rate"; (2) that the formation of $PbSO_4$ is proportional to the concentration of SO_2 for ranges encountered in the atmosphere; and (3) that the average rate of sulfate formation provides a useful measure of the activity of sulfur dioxide in the atmosphere. Investigations in England of environmental effects indicate that the rate of reactivity is not significantly altered by wind speed or change in relative humidity but increases with temperature and wetting of the lead peroxide surface.

While environmental factors may cause some change in the reactivity of lead peroxide, our limited studies suggest that these uncontrollable factors cannot be effectively correlated or adjusted even when detailed records of environmental conditions are available. Significant studies with controlled environmental conditions have not been made. However, it is our view that the variants of the environment do not lessen the usefulness of the technique. Therefore, we have been concerned with practical problems such as (1) shipment, storage, processing, and analysis; (2) change of reactivity with increased time (4) correlation of sulfation with recorded SO_2 concentrations; (5) practical control or reference values; and finally (6) the usefulness of the data in appraising air pollution from industrial sources.

Initial TVA Network

In TVA, networks of lead peroxide cylinders have been employed to obtain relative sulfation values at selected sites in the vicinity of large single sources. A network of about 40 cylinders was first operated within a radius of six miles of a steam plant for an eight-month period. While data from these installations provided some helpful relative sulfation values, the effectiveness of the network was impaired by inadequate consideration of meteorological, environmental, and cultural factors in site selection. For example, many cylinders were sited on hill or ridge tops, an unsound practice when it is recognized that air flow is similar to other drainage phenomena. Also, only one autometer was available in this area for correlation of lead peroxide sulfation with SO_2 exposure.

Results from a Second Network, Data Uses

As a network of six autometers was in operation in the vicinity of another steam plant, the lead peroxide study was moved to this area where 36 cylinders were exposed for periods of approximately one month each over a period of 13 months. Cylinders were operated in triplicate and duplicate at selected autometer sites. Information provided by this study established that:

1 A network extending only four miles from the plant was too small to provide a composite picture of stack gas dispersion in the area.

2 Large single point sources of SO_2 result in very low sulfation as compared with metropolitan or industrial areas, i.e., rates of 1–2 mg SO_3/100 cm²/day are not unusual in some urban areas.

3 Correlation of sulfation with SO_2 dosage is generally poor where average SO_2 level is as low as typically experienced at a single site near a point source.

4 In some instances sulfation present was not sufficient for effective analysis by barium sulfate precipitation.

5 Sealed cylinders retained in the laboratory have deficiences as control or reference values.

6 No correlation between sulfation of cylinders and sulfur in the foliage of a number of tree species existed, principally because no significant change in sulfur content of foliage occurred.

7 Values for triplicate cylinders at four sites did not vary over 10%, Table I.

8 An isopleth could be readily constructed from data obtained from a circumscribing network of lead peroxide cylinders.

Close agreement in sulfation rates at

Table I—Sulfation of Triplicate Lead Peroxide Cylinders

Reported in mg SO_3/100 cm²/day

Cylinder	Period 1	2	3	4	5	6	7	8	9	10	11	12	13
Location 1—1.4 Mi from Plant													
A	0.61	0.22	0.39	0.68	0.68	0.50	0.61	0.48	0.37	0.47	0.34	0.29	0.30
B	0.66	0.20	0.35	0.67	0.58	0.48	0.61	0.44	0.34	0.47	0.33	0.30	0.32
C	0.73	0.24	0.37	0.66	0.66	0.51	0.60	0.50	0.36	0.46	0.36	0.28	0.32
Location 2—3.3 Mi from Plant													
A	0.22	0.26	0.31	0.22	0.22	0.42	0.44	0.40	0.46	0.37	0.34	0.31	0.27
B	0.26	0.30	0.32	0.23	0.24	0.44	0.44	0.38	0.42	0.38	0.30	0.33	0.25
C	0.22	0.29	0.33	0.22	0.22	0.46	0.40	0.38	0.43	0.35	0.31	0.32	0.26

triplicate installations is evident in Table I. While there was a two- to threefold seasonal spread in reactivity values for cylinders at each of the locations, the replications have identical average and median values in many instances.

Reactivity Constant with Time of Exposure

The period of field exposure used in most lead peroxide cylinder installations has conventionally been one month. Needs may arise for a shorter or a longer exposure in certain situations. Plans were made in one area to initiate four-month surveys of 25 selected sites located 1–40 mi from the plant. The net of 36 cylinders located 1–4 mi from the plant having served its purpose was thus replaced by a network of cylinders at these and at four remote control sites. Investigation established that four-month exposure periods are quite practical and that reactivity of lead peroxide under local conditions is not attenuated in this period. Reactivity is essentially unchanged for periods of one, two, three, or four months. Data from these field tests are shown in Table II.

Sulfation at Great Distances

The network of lead peroxide cylinders employing a four-month cycle has been operated for about four years. Typical data from the network cylinders are illustrated in Fig. 3. Data are plotted from nine sites aligned in one direction 1.5 to 38 mi from the plant. It will be noted that the maximum value occurs at a distance of 5.5 mi while some smaller values exist nearer to the plant. This is a normal pattern attributed to the initial buoyancy of hot smoke plumes which tends to lift the plume above nearby ground level in periods of low and moderate wind velocity. The 12-fold range in sulfation rates is evidence that sufficient differential exists for evaluation of relative exposures at each site. The maximum and minimum values plotted for each site are a measure of the variation in exposure in 10 four-month sampling periods.

Establishing Realistic Field Control

In evaluating field data from lead peroxide cylinders, the appropriateness of comparing field values with a "sealed" laboratory control has been questioned, this being prompted by a presumption that some SO_2 is present in all atmosphere. Therefore, to establish realistic control values for comparison with values from an area of known higher value, four cylinders exposed for four-month periods were operated over a period of one year at remote sites 60 to 70 mi distant from SO_2 sources, one being at Clingman's Dome in the Smoky Mountains. In these "clean" areas

Table II—Reactivity of Lead Peroxide Cylinders

Cylinder No.	Exposure Period, Months	Mg SO_3/100 cm²/day				4-Mo Average
		May	June	July	Aug.	
1	1	0.40	0.20	0.17	0.32	0.27
2	2	(.....0.29.....)		(.....0.24.....)		0.27
3	3	(.....0.23.....)				—
37	4	(.....0.29.....)				0.29
38	1	0.28	0.26	0.31	0.36	0.30
39	2	(.....0.22.....)		(.....0.32.....)		0.27
40	3	(.....0.29.....)				—
41	4	(.....0.31.....)				0.31

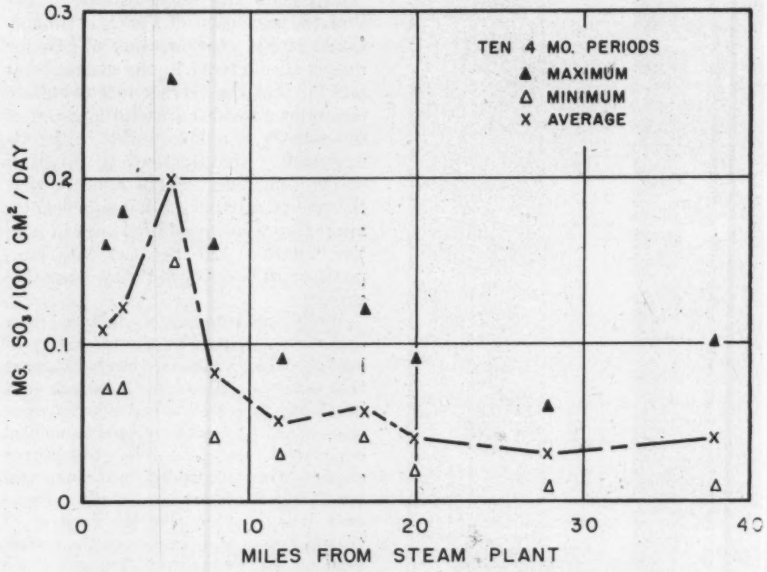

Fig. 3. Variation of sulfation rate with distance.

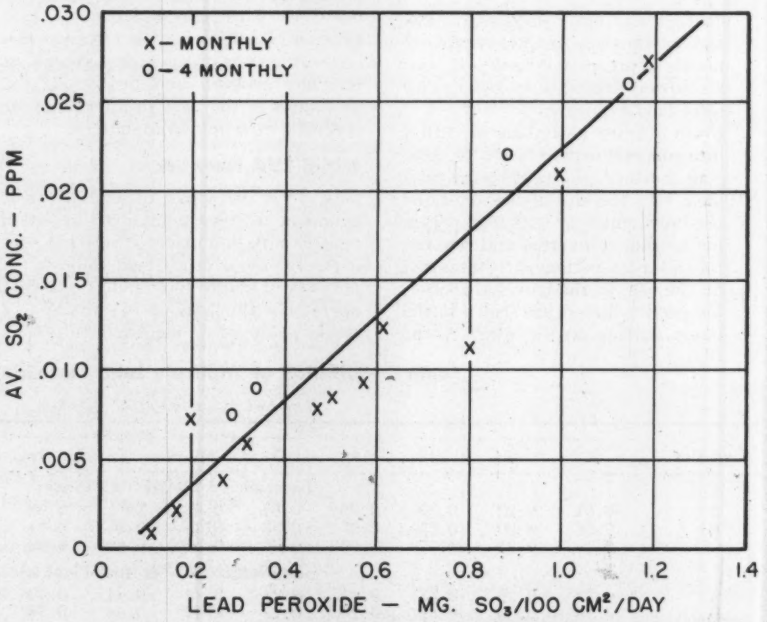

Fig. 4. Relation of sulfation rate and SO_2 exposure.

sulfation rates varied from 0.02 to 0.04 mg SO_3/100 cm^2/day. Thus, a value of about 0.03 mg SO_3/100 cm^2/day is considered to represent a realistic control value in this region. This is about an order of magnitude greater than rates established from "sealed" controls.

Relation of Sulfation and SO_2 Exposure

Data from lead peroxide cylinders operated adjacent to six autometers were analyzed to determine the relation between sulfation rates and SO_2 exposures or dosage. The data from all of the six locations reveal considerable scatter and a relatively low degree of correlation. This is attributed principally to the typical low average SO_2 dosage at most fixed sites near a single source. Low SO_2 dosages pose a dual problem: (1) Often sufficient sulfate is not present for accurate analysis. (2) The estimation of total SO_2 dosage from autometer charts is subject to wide variation in personal interpretation. A further factor which may result in different sulfation rates is suspected variable rate of oxidation of SO_2 in the atmosphere. Correlation is best at the site nearest the source where time for conversion of SO_2 to higher sulfur oxides is minimum.

Data from the station sited nearest the plant show greatest consistency in the relations between sulfation and SO_2 dosage. While these data plotted in Fig. 4 reveal some scatter, a definite consistency in the relation between sulfation and SO_2 dosage is evident. In Fig. 4, it may be noted that at this site of maximum exposure the average SO_2 concentration was about 0.02 ppm. For comparison the average SO_2 concentration in New York City for 1956, 1957, and 1958 has been reported as 0.21, 0.20, and 0.16 ppm, respectively. For similar average SO_2 concentrations, sulfation rates are essentially the same as those found by Foran, Gibbons, and Wellington in their extensive studies of the lead peroxide technique near Trail, B. C.

Summary

In summary, field experience in the use of lead peroxide cylinders for evaluating sulfur dioxide reactivity in the vicinity of large coal-burning steam plants has been described. The cylinders are considered to provide a useful and economical means of estimating integrated SO_2 exposure. In an area of moderate or average concentration, a high degree of correlation was noted between SO_2 exposure and lead peroxide sulfation. No deterioration in the rate of reactivity of lead peroxide with SO_2 was noted in periods as long as four months.

This technique might be even more useful in certain urban and industrial areas or in remote areas where power operated instruments cannot be used. Data from lead peroxide cylinders are useful in providing an estimate of corrosion potential[3] as well as a measure of air pollution control. The higher average SO_2 concentrations in urban or industrial areas should enhance effectiveness and largely eliminate analytical problems associated with low sulfation rates. Increased sensitivity may now be obtained by advanced analytical techniques, one being the colorimetric procedure described by S. Kanno.[4]

Acknowledgments

We wish to acknowledge the contribution of C. W. Kruse, who initiated the use of lead peroxide cylinders in TVA; also of A. E. Owen and J. P. Terry who developed the very helpful technique for storing, shipping, and sealing of freshly prepared or exposed cylinders.

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A SIMPLIFIED METHOD *for* DETERMINING OZONE LEVELS *in Community* AIR POLLUTION SURVEYS*

THEODORE VEGA, Air Pollution Chemist I, **CLIFTON J. SEYMOUR**, Air Pollution Engineer
Riverside County Air Pollution Control District, Riverside, California

One of the tasks confronting air pollution control agencies is that of determining levels of air contaminants over a given area or at specific locations. As everyone knows who has looked into this phase of air pollution measurements, there are specific automatic instruments available for continuous air monitoring for oxidant, ozone, oxides of nitrogen, sulfur dioxide, carbon monoxide, and fluorides. These instruments are relatively expensive. Specialized and trained technicians are needed to operate and maintain them.

It would seem, then, that a simplified, accurate, and relatively inexpensive method should be developed and used for community air pollution surveys, if the necessary data are to be collected. This is especially true where agencies desiring to make these surveys are being operated on a very low budget.

In some air monitoring groups, there are questions being raised as to the actual value of collecting volumes of continuous recorded data on air contaminant levels since the reduction and use of the data for comparative purposes seems to be difficult, if not impossible. A simplified method for determining average figures by cumulative data may be much more significant. Following this school of thought, a method for determining ozone levels in community air pollution surveys was developed, and is reported in this paper.

The sampling procedure was developed with a view to its cost and simplicity of methodology. Bench work in the laboratory has been simplified so that the manipulation can be performed by any trained technician with equipment that is available in the average laboratory.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

Modified Rubber Cracking Method Used in Survey

This paper presents an intensive six months' study of the application of a unique modification of the rubber cracking method for ozone determination in a survey conducted in Riverside County, Calif., to determine average ozone levels in the area.

In the past, cumulative cracking of rubber has been investigated to determine the effect of ozone on synthetic and natural rubber[1] and ozone cracking of rubber goods in the Los Angeles area.[2] In both of these investigations, it was determined that an actual quantitative linear relation exists between the extent of crack depth in the rubber strip and the exposure time to a given concentration of ozone. This suggested to the writers that the rubber cracking method might be a very simple but accurate method for determining ozone levels in community air pollution surveys.

The method adopted by the Riverside County Air Pollution Control District for its survey on area levels of ozone contamination is a modification of the work developed and reported by Rugg.[1] It has been primarily modified in the sampling approach and the calibrating procedure in order to meet the specific needs of the District, and to keep the methodology and equipment in sight of the original aims of low expense and simplicity of operation.

The rubber strips used in this study were 40 mm long, 8 mm wide, and $^1/_{16}$ in. thick, compared to the 6-in. by 1-in. by 0.10-in. strips used by Rugg. The formula for the rubber stock used in the cumulative rubber cracking test strips and calibration strips is the same as that given in the procedure used by the Los Angeles County Air Pollution Control District for determining ozone by the rubber cracking method.[3]

The cracking effect of ozone on rubber is only experienced when the strip is under strain, in a bent or stretched position. In the method used in this survey, a constant load was used to initially elongate the rubber by 10%. The constant load method of sample exposure was selected because it has been proposed as a more sensitive method for ozone exposure.[4]

There has been no attempt made to repeat the investigation of other workers on the effect of exposure time vs. depth of crack on cumulative rubber cracking, since it has been investigated and reported that a substantially linear relation exists between average depth of crack and exposure time.[1, 2]

The sampling procedure used in the method reported in this paper consists of the suspension of a previously calibrated rubber strip under a constant load, and exposing it under this condition for a predetermined period of time. In the study reported here, lead weights totaling 360 g were used to elongate the strip.

The rubber strip is held in place between the wire suspending it and the lead weights by two LEB No. 2 small binder clips, one clipped on either end of the length of the rubber strip. One clip is held by a wire from the top of the sample holder; the other clip holds the lead weight. The rubber strip is shielded from the direct rays of the sun on all sides, and on the top. The metal sample holder used to shield the sample has four small ventilation holes, to allow a gradual change of air within the container. The purpose for this type of sampler holder is to reduce the air moving past the suspended strip to a minimum flow.

In developing the sampling procedure for the present method that is being used for determining ozone levels, a period of one month was initially selected for the exposure. It was

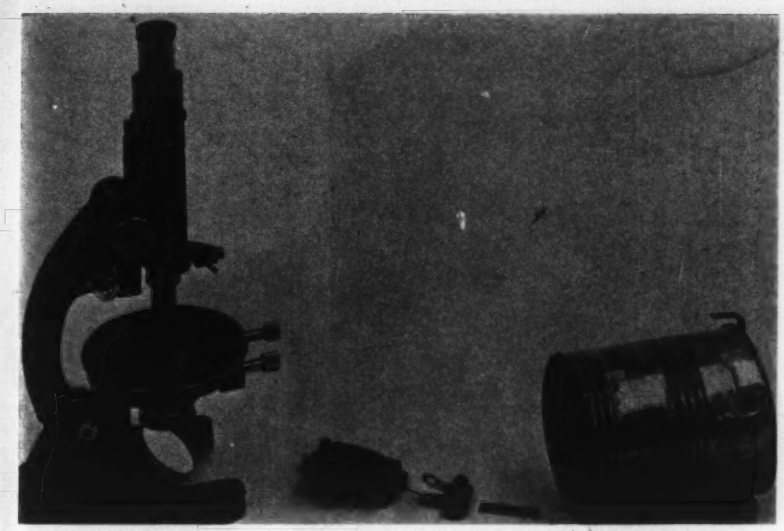

Fig. 1. Equipment used to determine ozone levels by modified rubber cracking method.

found, however, that in some locations, the rubber strip would crack so deeply that the weight would cause the rubber strip to break. The second exposure time selected was for a 15-day period, and this was found to be very satisfactory for a readable depth of crack at the seven sampling stations. The schedule being followed at present is to change rubber strips on the first and sixteenth of each month, thus having 15- or 16-day periods of cumulative cracking on each rubber strip.

On removal of the rubber strips from the sample holders at the end of the sampling period, they are stored in one dram "Titeseal" glass vials for later evaluation in the laboratory.

Equipment Required for Modified Rubber Cracking Method

The equipment required for using the rubber cracking method to determine ozone levels in a community air pollution survey can be quite elaborate, or, as used in this study, very simple. Figure 1 shows the essential pieces of equipment used for obtaining the average ozone concentration data reported in this paper. These are as follows:

1 A number $2^1/_2$ metal can, with the bottom removed and four holes spaced equally around the upper rim to cause natural ventilation within the can. This container shields the rubber strip from the sun rays and weather. A small metal hook is located on the top. This is to hook the can over the edge of a wooden box, which contains the dustfall equipment located at the various air monitoring stations.

2 Two small binder clips are used to hang the rubber strips in the proper position. One clip is secured by a piece of wire fastened to the center of the top of the inverted can. This clip is snapped on to one end of the rubber strip, which is suspended lengthwise. The other small binder clip is attached to the weight used for the constant load tension, and which elongates the rubber strip.

3 A weight to elongate the rubber strip, and furnish the constant load. Both large lead weights and small lead rods cut to the proper weight were used. It was found, however, that an easier way to prepare the weight used for constant load, is to fill a small metal can with lead wool, until the desired weight is achieved.

A 40 mm by 8 mm by $^1/_{16}$ in. thick rubber strip was used for the sample strip. Although the actual size for this method is, for all purposes, immaterial, once the particular size is chosen and adapted to the needs of the operators, it is important that this dimension be retained throughout the survey. The reproducibility of the method depends, in large part, upon the properties of the rubber stock used. The material must be sensitive to ozone, and uniform in quality. The formula for the rubber stock used is that reported in the Los Angeles County APCD procedure for determining ozone by the rubber cracking method.[3]

5 A microscope of the type normally found in the average laboratory can be used for determining the length of cracks in the rubber strip. In the work reported by Rugg,[1] the length of cracks was measured by using a 20x microscope, having a micrometer eyepiece. A 50x microscope, with a micrometer eyepiece giving 0.02 of a millimeter per division, was used to measure the depth of the cracks as reported in this study.

6 A die for making a "heart" cut from the rubber strip for examination under this microscope is very desirable. However, in this study, a razor blade and a jig were used to make the necessary trimmings.

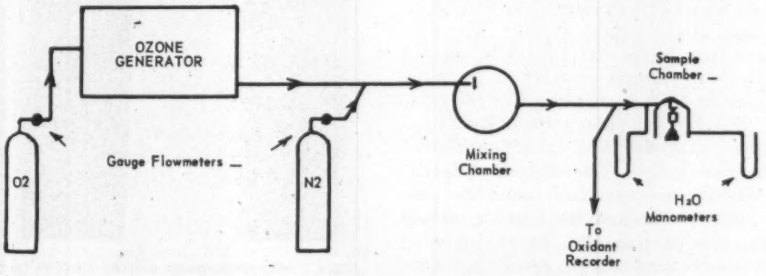

Fig. 2. Schematic drawing of calibration equipment.

In addition to the above, it is very desirable to have at one's disposal, a calculating machine to calculate quickly and accurately the average crack depths from the numerous readings made on each rubber strip.

Laboratory Bench Work

The laboratory bench work involved in this method is relatively simple, and can readily be performed by any trained technician.

After the collection of the exposed rubber strips, they must be prepared for examination under the microscope. This is done by using a dye or sharp razor blade to make a "heart" cut from the exposed strip. Care must be taken to avoid tearing or beveling the edges. Properly cut stock should present a smooth rectangular cut when viewed endwise.

In the procedure followed in this study, the "heart" cut is prepared by cutting 25% of the total original length off each end of the strip and 25% of the total original width off each side of the strip.

The depth of the cracks is measured with the microscope on the relaxed longitudinal cross section made normal to the length of the cracks. The sample containing the cracks is scanned, and the deepest cracks are measured, because they are the active ones. The shallower cracks have ceased to have a directing influence in the cracking.[5]

The cracks which are less than 10% of the deepest cracks are not included in the sum for the determination of the average depth of crack.

Results of this investigation show that the two contiguous edges on one cross section substantially give the same average depth of crack as the other two edges on the opposite side of the same strip. Thus the average depth

Fig. 3. Equipment used to calibrate rubber stock used in survey.

of crack as reported in this paper represents the readings of the two edges on one face only of the cross section.

Calibration Procedure

The preceding discussion has pointed out that in the modified rubber cracking method, the crack depth, exposure time, and ozone concentration are related. Also, that a method has been developed for laboratory use, for determination of the average crack depth on a rubber strip, which has been exposed to atmospheric ozone for an extended period of time. To be able to use the above information, and apply it to the simplified method for determining ozone levels in community air pollution surveys, the rubber strips must be calibrated so the depth of crack observed on the rubber strip exposed to the atmosphere can be converted to show the average ozone concentrations to which the strip has been exposed.

To calibrate the rubber strip, an attempt was made to simulate field conditions as much as possible. Figure 2 is a schematic diagram of the process that was used for calibration of the rubber strip. In following the flow on the schematic drawing, it can be seen that the oxygen enters the ozone generator at the left. The ozone generator consists of a large glass chamber in which is suspended an ultraviolet lamp. The amount of ozone manufactured at this point can be controlled by the power pack, which consists of a constant voltage regulator, a variable rheostat, and a step-down transformer.

Following the ozone generator, nitrogen is introduced, to dilute the ozone stream. This is used both for controlling the ozone concentration, and making an oxygen-nitrogen mixture similar to the atmosphere.

After the nitrogen gas is added, the stream flows into a mixing chamber. This chamber is approximately $8^1/_2$ in. in diam, and assures that the ozone laden oxygen is completely mixed with the nitrogen used for dilution. From the mixing chamber, the gas flow is split between the potassium iodide continuous oxidant recorder, and the sample chamber.

In the calibration procedure followed, the continuous oxidant recorder is used to determine the desired ozone concentration that is being supplied to the sample chamber, and also to record the concentration of ozone to which the rubber strip is subjected during the calibration runs. The oxidant recorder is calibrated using known concentrations of ozone, and therefore, the ozone stream going to the recorder can be read directly in parts per hundred million of ozone.

Only a very low flow is allowed to pass through the sample chamber. This is determined by two methods. One is by observing the flow gages located at the oxygen and nitrogen cylinder outlets, and the other method is to observe the water manometer that has one leg attached to the gas inlet line to the sample chamber. A second water manometer, with one leg attached to the sample chamber, will give a positive indication, if there is a small flow through the sample chamber.

Dimensions of the sample chamber are about $5^1/_2$ in. high, and $4^1/_2$ in. in diam at the largest section. The rubber strip to be calibrated is suspended inside the sample chamber, in the same manner as it is suspended in the field.

Figure 3 is a photograph of the equipment that was used in calibrating the rubber strips. The oxygen cylinder, nitrogen cylinder, and continuous oxidant recorder were too large to include in this photograph. After examining the schematic diagram, it will be obvious as to where these three items are connected into the system.

Rubber Strip Calibration Test Runs

Two very important variables were investigated during the rubber strip calibration test runs. One was the effect on the crack depth of the velocity of the gas contacting the rubber as determined by the rate of flow, and the other was what influence the temperature at which the reaction takes place may have. Both of these variables are very important, because if they prove to significantly effect the depth of the crack, then a rubber cracking method to determine ozone levels in community air pollution surveys would be very inaccurate, and not comparable at dif-

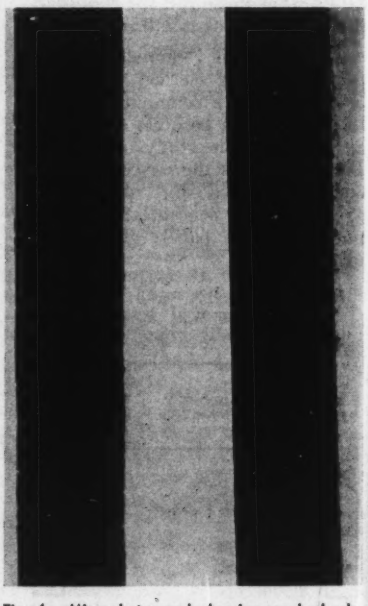

Fig. 4. Microphotograph showing cracked rubber strips.

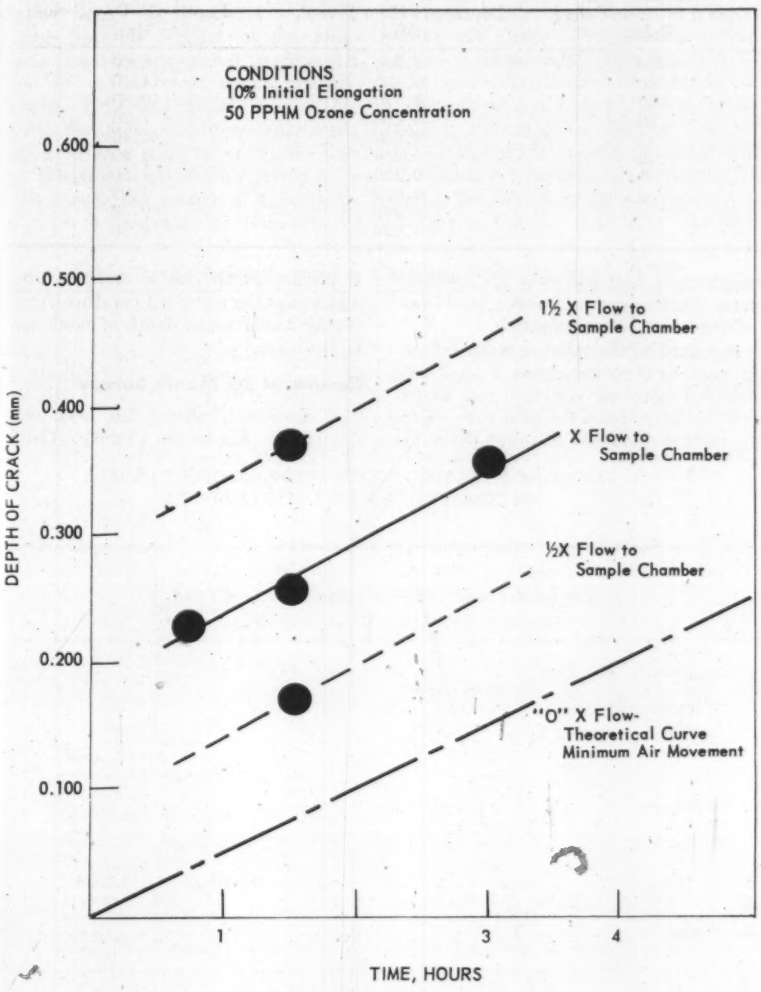

Fig. 5. Crack depth vs time.

ferent seasons of the year.

The first phase of the investigation was to determine what effect the rate of flow has on the depth of cracking of a rubber strip, which is suspended during the survey period. For Test Run No. 1, a flow which can be designated as "X" was allowed to pass through the sample chamber of the calibration equipment. An ozone concentration of 50 pphm was maintained for one and one-half hours, at 77°F (25°C). The average depth of cracks in this strip was determined by the procedure outlined under the section of this report on laboratory bench work. All depth of crack measurements on rubber strips used in the calibration runs were determined using the same procedure.

In Test Run No. 2, the flow, ozone concentration, and temperature were the same as in Test Run No. 1, but the time for which it was exposed was increased to three hours. The rubber strip from this test is shown in Fig. 4, and is the right one of the two in this microphotograph. The left rubber strip is one that was used in the survey. This illustrates how much more pronounced the cracks are as a result of being suspended for 15 days. In the photograph, it is very difficult to find the crack in the rubber strip used for this test run. In order to obtain the measurements more accurately, the strips used in the calibration runs had to be elongated slightly, to open the cracks.

Test Run No. 3 was also made with the flow, ozone concentration, and temperature the same as in Test Run No. 1, but the time of exposure was decreased to three-fourths of an hour.

The resulting average depth of crack measured in the three rubber strips of the first three test runs are as follows:

Run No.	Average Depth of Cracks, Mm
1	0.262
2	0.352
3	0.228

The above data are plotted on the chart in Fig. 5, and the line entitled "X Flow to Sample Chamber" results. This line gives the average crack depth in millimeters that can be expected at various exposure times, when the rubber strip is exposed to 50 pphm of ozone at 77°F and X flow.

After the slope of the line was established at X flow to the sample chamber, two additional test runs were made using $^1/_2$X flow, and $1^1/_2$X flow.

Test Run No. 5 was made using one-half the flow to the sample chamber of that used in Test Runs Nos. 1, 2, and 3. The rubber strip was exposed to an ozone concentration of 50 pphm for one and one-half hours, at 75°F (24°C).

The flow to the sample chamber in Test Run No. 6 was increased to one and one-half that used in Test Runs Nos. 1, 2, and 3. The exposure time and ozone concentration was the same as in Test Run No. 5, and the temperature was 70°F (21°C).

The results from the two above tests are shown below:

Run No.	Average Depth of Cracks, Mm
5	0.168
6	0.372

These data are plotted on the chart shown in Fig. 5, and lines of the same slope as the one determined by Test Runs Nos. 1, 2, and 3 are drawn through the points.

From the family of curves produced by data from Test Runs Nos. 1, 2, 3, 5, and 6, plotted in Fig. 5, a theoretical curve at "0" X flow is drawn through the intercept of the two axes. This theoretical curve shows the relationship between the average crack depth and the period of time that the rubber strip is exposed to an ozone concentration of 50 pphm at minimum flow. It was selected as the calibration curve for the rubber strips that were exposed to the atmosphere in the study being made to determine ozone levels in community air pollution surveys because, in following the procedure for hanging the strips, there will be only a minimum air flow inside the metal can used for protecting the strip.

From the rubber strip calibration curve at "0" X flow, it can be seen that at an ozone concentration of 50 pphm, the average crack depth for one hour exposure was 0.050 mm. This would

be cumulative, and if exposed for a 24-hour day, will reach an average crack depth of 1.20 mm. Using these basic data, and the fact that a quantitative linear relation exists between the extent of crack depth in a rubber strip and the average cumulative concentrations of ozone present in the atmosphere, the relationship in Table I is developed.

It should be pointed out that the above relationships only hold for the rubber stock that was calibrated in this investigation, and used in the six month survey which is reported later in this paper.

The data in Table I, showing the cumulative crack depth which was calculated for the 15-day exposure period is plotted versus the average ozone concentration over a 24-hour period, and is shown on the chart in Fig. 6. A similar chart was made for a 16-day period, thus enabling a direct conversion from the crack depth measured in the rubber strips that were exposed for a 16-day period to average ozone concentration over a 24-hour period.

Temperature Effects

Following the investigation on the effect that the rate of flow of the gas contacting the rubber strip has on the crack depth, two more test runs were made, to determine if the average temperature experienced at different seasons of the year will have a significant effect on the results of the rubber cracking tests.

Test Run No. 7 was made with X flow to the sample chamber, an ozone concentration of 50 pphm, for an hour and a half exposure, at a temperature of 59°F (15°C). Test Run No. 8 was made under the same conditions as Test Run No. 7, and the temperature was held at 95°F (35°C).

Below is a comparison of the results obtained at three different temperatures, which will cover the average temperatures experienced during the six months in the area in which the survey reported was made.

Run No.	Temperature	Average Depths of Cracks, Mm
1	77	0.262
7	59	0.246
8	95	0.274

Upon examination of the above data, it would appear that variations of the average temperatures experienced in the field in Riverside County, Calif., would have very little effect, if any, on the relationship between the ozone concentration in the atmosphere and the related depth of cracking of a rubber strip. This would apply only to the rubber stock that was used in these test runs. Other types of rubber would require a separate investigation.

In regard to the effect of temperature on cracking of rubber strips, it has been observed both on the test run strips and the strips from the field tests, that the number of cracks observed per strip is greater at the higher temperatures, and less at the lower temperatures, even though the average depth of crack may be the same.

Table I

Average Ozone Concentration Over a 24 Hour Period, Pphm	Average Cumulative Crack Depth—24 Hour Period, Mm	Average Cumulative Crack Depth—15 Day Period, Mm
50	1.200	18.00
40	0.960	14.40
30	0.720	10.80
20	0.480	7.20
15	0.360	5.40
10	0.240	3.60
5	0.120	1.80
3	0.072	1.08
2	0.048	0.72
1	0.024	0.36

Results of Six Month Survey

A six-month survey has been conducted in Riverside County, Calif.,

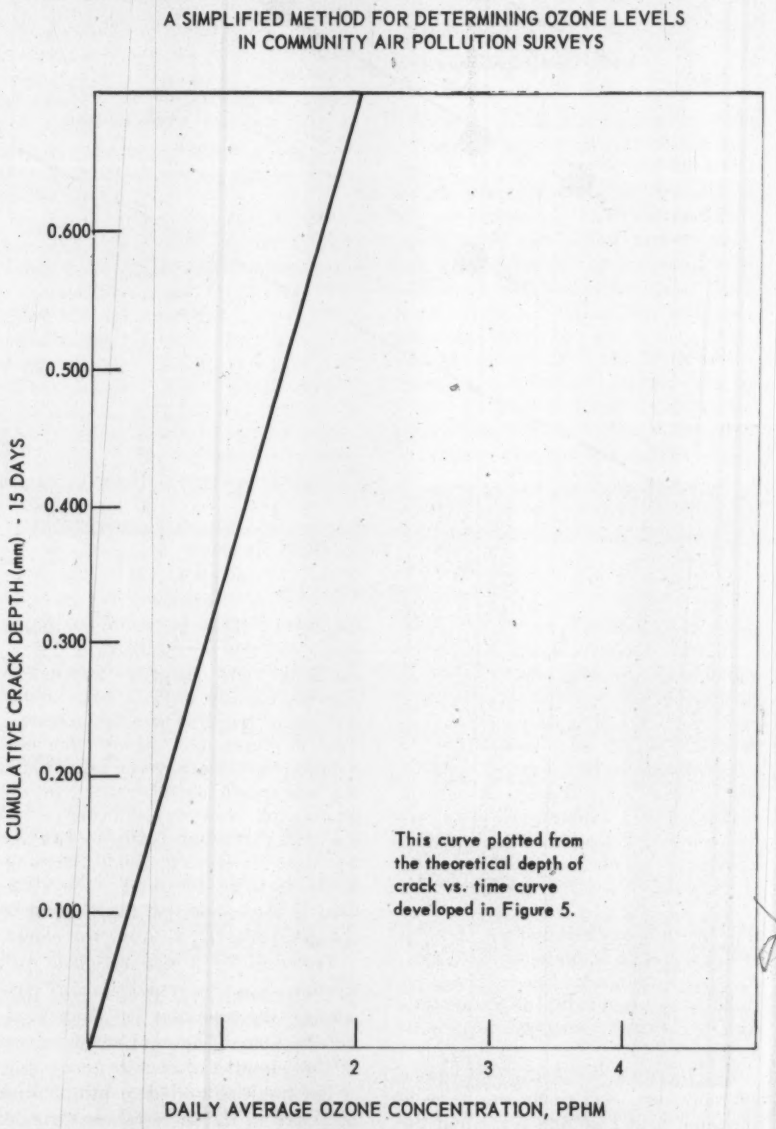

Fig. 6. Cumulative crack depth vs average daily ozone concentration.

using the modification of the rubber cracking method for ozone determination described previously in this paper. Rubber strips were located at seven sample stations throughout the area. Table II has been prepared to show the type of results that were obtained. October, 1959, was chosen, because this month had high oxidant recorder readings a greater number of times than any others covered by the survey.

To reduce the volume of data tabulated, results from the six-month survey, using the cumulative rubber cracking method for determining ozone levels are presented in Table III from only one sample station, located in the City of Riverside, Calif. This table shows that there is considerable difference in daily average ozone concentrations during the different periods tested. For example, during the period of October 1 to 16, an average daily ozone concentration of 1.1 pphm is reported compared with 0.4 pphm for December 16 to January 1.

Due to the fact that there was such a large difference in the average daily ozone concentrations between the two periods compared above, it was decided that the oxidant reading from the potassium iodide oxidant recorder at the same stations for these periods be compared with the results obtained by the rubber cracking method. Table IV shows what correlation exists between the ozone levels obtained by the cumulative rubber cracking survey, and the oxidant levels recorded for the same period. Although there cannot be a direct correlation made, since one is a measure of ozone, and the other of oxidant, it is very apparent that the average ozone concentrations determined by the rubber cracking method are very indicative of the level of ozone concentration during the periods that are compared.

Table II—Cumulative Rubber Cracking Tests (October, 1959)

Station No.	Average Depth of Crack, Mm— For Period of: October 1–16	Oct. 16–Nov. 1	Daily Average Ozone Concentration, Pphm— For Period of: October 1–16	Oct. 16–Nov. 1
1	0.392	0.362	1.1	0.9
2	0.358	0.308	1.0	0.8
3	0.454	0.554	1.3	1.4
4	0.318	0.340	0.9	0.9
5	0.272	0.286	0.7	0.8
6	—	0.334	—	0.9
7	0.380	0.446	1.1	1.1

Table III—Cumulative Rubber Cracking Tests

Six-Month Survey, City of Riverside, California

Sampling Period	Average Depth of Crack, Mm.	Daily Average Ozone Concentration, Pphm
August 1–16	0.242	0.7
August 16–September 1	0.246	0.7
September 1–16	0.240	0.7
September 16–October 1	0.270	0.7
October 1–16	0.392	1.1
October 16–November 1	0.362	0.9
November 1–16	0.346	1.0
November 16–December 1	0.292	0.8
December 1–16	0.344	1.0
December 16–January 1	0.138	0.4
January 1–16	0.366	1.0
January 16–February 1	0.362	0.9

Table IV—Correlation Between Oxidant Levels and Ozone Levels by Cumulative Rubber Cracking Survey

Sampling Period	October 1–16			December 16–January 1			
Daily Average Ozone Concentration, Pphm	1.1 Oxidant Levels, Pphm				0.4 Oxidant Levels, Pphm		
Hours Exceeding →	5	10	15		5	10	15
October 1	1½			December 16	4½		
2	4			17	5		
3	2			18	6		
4	9½	3		19	0		
5	9	4		20	0		
6	9½	3½		21	0		
7	7			22	0		
8	10	8	1½	23	0		
9	10½	7		24	0		
10	11½	7½		25	0		
11	12	9	2	26	0		
12	9	6		27	3		
13	4			28	0		
14	8½	4	1½	29	0		
15	6½	5		30	3½		
				31	0		
Total Hours	114½	57	5		22		

Oxidant levels determined by continuous K1 oxidant recorder.

Summary and Conclusion

The necessity to make a community survey to determine levels of ozone contamination in the Riverside County Air Pollution Control District brought along with it the need for a simplified inexpensive method to conduct such a survey. It is definitely felt that the procedure for the determination of average ozone values, as outlined in this paper, amply covers all the requirements of accuracy, reproducibility, and methodological simplification necessary of such a procedure.

To summarize, the sampling equipment is simple, and within reach of the most modest agency. The procedural handling has been simplified to where any average trained technician will be able to capably perform the necessary operations. The laboratory equipment required has been reduced to that which is normally found in the average laboratory.

Through one series of experiments, it has been shown that if the flow is maintained as nearly that of change of surrounding air or, in other words, a minimum flow, the effect of flow as shown by other investigators is obviated so that the reaction curve approaches an ideal linear relation. In a second series of experiments, it was found that the effect of temperature within the ranges reported also appears to be negligible. These two factors are very important when considering the relative results between different areas and periods of time.

Of great importance in the reported approach to the problem is the fact that, through this method, the interpretative abilities of different operators are eliminated, and, therefore, the relative values obtained by different operators may be evaluated between different areas and periods of time more accurately.

Of over-all importance is the choosing of the longest possible exposure time,

(*Continued on p. 44*)

Application of GAS CHROMATOGRAPHIC METHODS for Air Pollution Studies*

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In recent years air pollution control has become a more and more acute problem. Intensive studies in many places are dealing with the origin, quality, and effect of air pollutants and with methods for their elimination. The preliminary condition of all of these studies is that suitable methods and instruments permit the determination of the nature and amount of the contaminants in air.

Because of the importance of the problem, many types of instruments have been applied to air pollution studies.[1] Some of them, as, e.g., the recording nitric oxide and nitrogen dioxide colorimeter,[2] or infrared spectrophotometers equipped with long path cells[3–5] proved useful in such investigations.[6]

Since the development of gas chromatography, this analytical method proved that it "..... can be considered as one of the greatest analytical achievements of all time."[7] The biggest advantages of gas chromatography are its extremely high sensitivity, the relatively short time of analysis and the excellent separation effect obtained for most compounds. It is therefore self-evident that this method would be applied in the first years of its development for studies in analyzing trace contaminants in gases.

Gas Chromatography in Trace Analysis

Gas chromatography has two limitations in its application to pollution studies. The first limitation is that if components of a wide boiling range or different characters are present in the sample, the analysis often cannot be carried out in one run because it is very hard to find "general" chromatographic columns. The second limitation is that, although gas chromatography shows an extremely high sensitivity, it is not high enough for air pollution studies when using standard analytical techniques.

Let me discuss briefly these two problems.

Wide-Range Analysis

Particularly in engine exhaust gas studies, the wide range of components present in gas makes the separation and analysis of these components difficult in one run. For instance, C_2–C_5 hydrocarbons could be separated satisfactorily by a semipolar liquid phase, in a relatively long chromatographic column. On the other hand, the C_6–C_8 paraffins and naphthenes, C_5–C_7 olefins and C_6–C_7 aromatics will emerge from this column only in a relatively long time. However, they are easily separated by other columns. This problem can be solved using special arrangements where several columns are used in series.

In 1958–59 special gas chromatographic instruments were described[8–14] for the solution of this problem. These instruments apply the *multiple stage system* and include two to four separate stages which may be operated in series. In making a wide range analysis, conditions may be chosen so that each stage may contain the column system best suited for the separation of components in only one segment of the sample.

Figure 1 shows the flow schematic of a typical three-stage commercial instrument† and Fig. 2 illustrates the fractograms obtained using such a triple stage instrument in hydrocarbon analysis. The C_6–C_7 hydrocarbons were analyzed on the first column containing di-2-ethylhexyl sebacate as stationary phase; the second, dimethylsulfolane column was specific for the C_3–C_6 isomers and, the third, silica gel column made possible the analysis of air CO, CO_2, and C_1–C_2 hydrocarbons. Analysis of samples with up to 58 components is given in the literature.[13]

Sampling Techniques

The main limitation of gas chromatography for applications in air pollution studies is that the concentration of the pollutants in the air is so small that the sensitivity of the method is not sufficient for directly analyzing a gas sample in a conventional gas chromatograph.** However, by adding a concentration step (already common practice in air pollution studies[15, 16]) to the conventional chromatographic technique, and using a highly sensitive recorder, the useful range for the components of interest can be extended to, or below, 1 ppm concentration.

The use of such condenser systems for gas chromatography was first described by Ford and Rogers,[18] Rhoades[19] (who used it in the food field), and Eggertsen and Nelsen,[20] and was applied by many authors for the analysis of trace contaminants in gases.[21–23] These authors, however, used specially built instruments for the analysis. About one and a half years ago we also investigated the problem of the condensing techniques and built a simple system which adapts itself to a commercial gas chromatograph†† for the determination of trace impurities in gases.[25] This system is a simple modification of the standard Perkin-Elmer precision gas sampling valve,[26, 27] and its schematic is shown in Fig. 3.

The purpose of this system is to pass large volumes through a condenser which is cooled to collect the impurities of interest. The main part of it is a *condenser column*, about 50 cm long, 0.25 in. outside diam, which is installed in place of the interchangeable sample volume tubing. A pressure and flow regulator, a flow meter, and a Dewar flask complete the equipment. Figure 4 shows the photo of the system installed on the wall of a standard gas chromatograph.

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* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

† Model 188 Triple Stage Vapor Fractometer of the Perkin-Elmer Corp.

** Under "conventional gas chromatographs" I mean those which contain thermal conductivity detectors and make use of packed columns.

†† The Model 154 Vapor Fractometer of the Perkin-Elmer Corp.

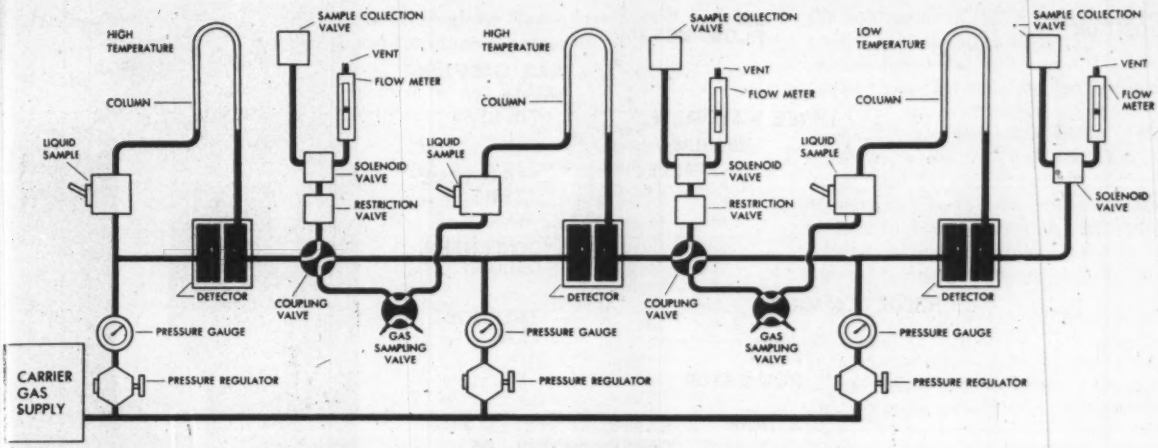

Fig. 1. Flow schematic of a typical three-stage commercial instrument.

The condenser column is filled with a substance which adsorbs the investigated impurities at low temperatures and will liberate them at some convenient elevated temperature. The carrier gas flow and the main component of the sample should only be adsorbed slightly, or not at all.

The system operates as follows: First, the condensing column is cooled with dry-ice acetone (or other coolant) and a fixed amount of sample is run under known flow conditions through the system (position 1). During this operation, the trace impurities and some of the main components will condense in the column. After passing the appropriate sample volume, the condenser is closed off from the sample tank and its exit is momentarily attached to a vacuum line in order to remove the matrix gas which fills the column. If necessary, a special purging step would be useful to remove the matrix gas from the adsorbent column. After completion of the procedure, the coolant is removed and replaced with a hot-water bath. When equilibrium has been attained at this elevated temperature, the condenser tube is

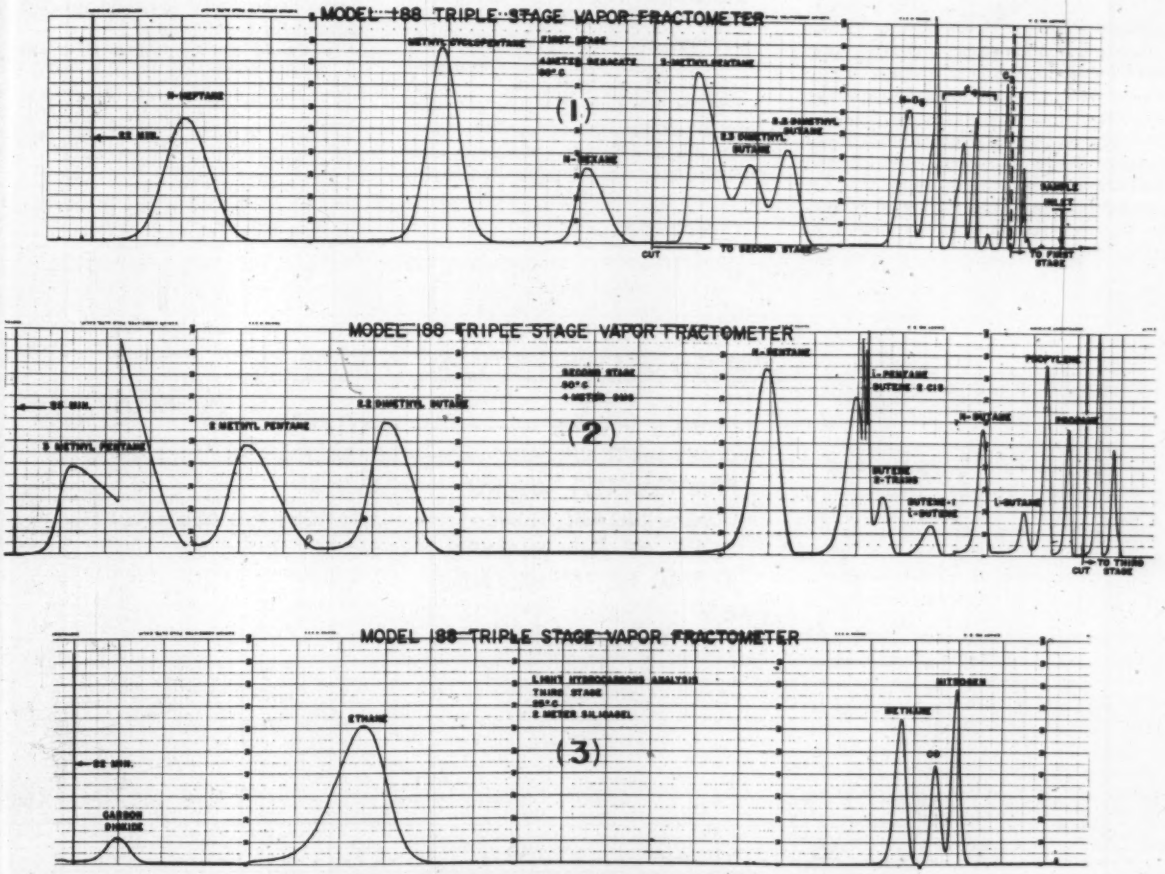

Fig. 2. Fractograms obtained using a triple stage instrument in hydrocarbon analysis.

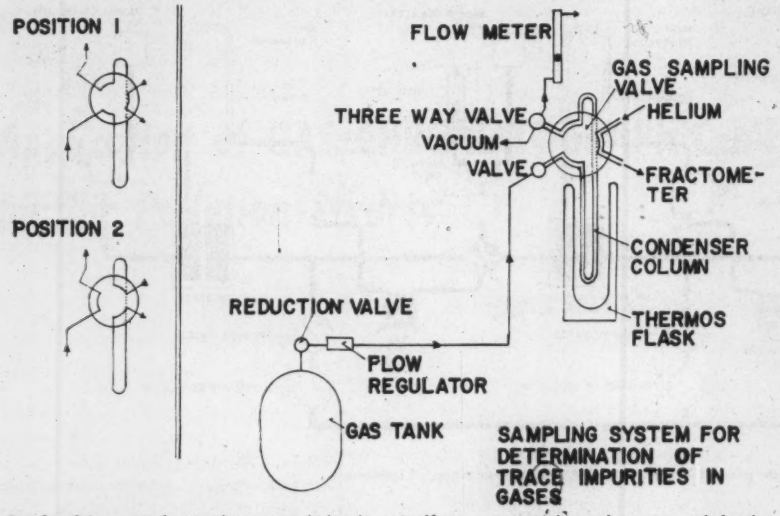

Fig. 3. Schematic of a simple system which adapts itself to a commercial gas chromatograph for the determination of trace impurities in gases.

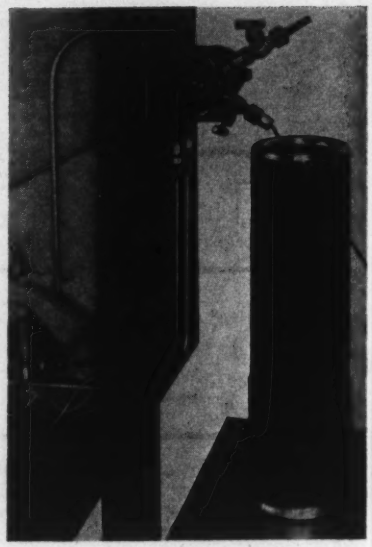

Fig. 4.

connected to the gas chromatograph (position 2). In this way, the components desorbed from the condenser will pass with the carrier gas to the gas chromatograph and be analyzed.

The applicability of our system has been tested in many cases. As an example, Fig. 5 shows the analysis of 4 ppm acetylene in air. The selected chromatographic column was 2 m silica gel; the same material was used for filling the condensing column. In this case, the minimum detectibility is at 0.13 ppm concentration, using a 10 l sample, but with larger amounts of sample this value could be lowered well below 0.1 ppm.

Another example for this technique is the analysis of trace impurities in electrolytic hydrogen gas. The concentration of the impurities was as follows:

oxygen	155 ppm
nitrogen	4900 ppm
carbon monoxide	10 ppm
carbon dioxide	10 ppm
methane	610 ppm
higher hydrocarbons (sum)	20 ppm
water	100 ppm

Figures 6–8 show the corresponding chromatograms indicating the conditions used for the analyses. The column materials corresponding to the used abbreviations are as follows:

I: molecular sieve 5A

J: silica gel

E: dimethyl sulfolane on Chromosorb

K: poly(ethylene glycol) on Chromosorb

The reproducibility of the analyses is shown in Tables I and II. The minimum detectibility is even in these cases at 0.1 to 0.5 ppm.

It should be mentioned that other condensing techniques are also reported[24] where the impurities were collected in a solvent and the resultant solution was analyzed. All of these investigations show that the opinion[17] that "... present gas chromatographic techniques do not have the sensitivity to determine solvents in air at most threshold con-

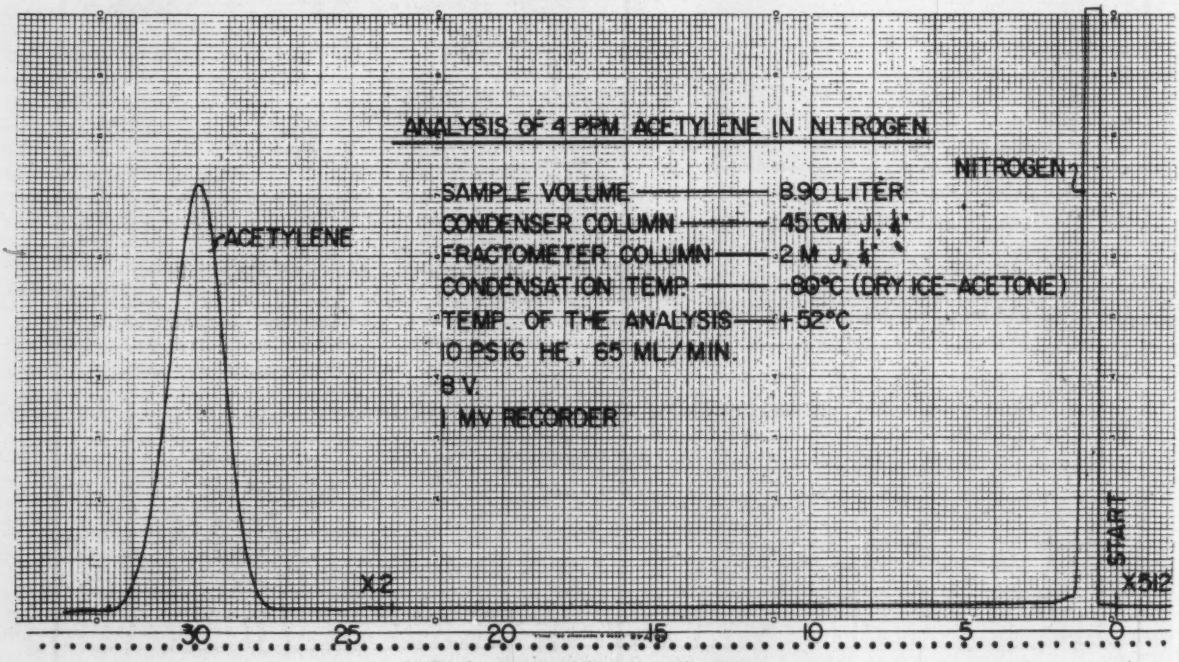

Fig. 5. Analysis of 4 ppm acetylene in air.

Table I—Analysis of the Impurities in Electrolytic Hydrogen with 2 m Silica Gel Column with the Condensing System

The conditions of the analyses are given in Fig. 8. Sample volume: (a), (b) = 16 l.
A: Average values of (a) and (b).

Component	Analysis	Attenuation (S) of the 1 mV recorder	Peak height (H), in.	Peak width at half height (W), in.	Peak height at max attenuation[a] (S × H), in.	Deviation from the avg peak height, %	Peak area at maximal attenuation (S × H × W), sq in.	Deviation from the avg peak area, %
Methane	a	128	8.525	0.11	1091.2	0	120.026	0
	b[b]	128	8.525	0.11	1091.2	0	120.026	0
	A				1091.2		120.026	0
Ethane	a	8	6.20	0.33	49.60	−0.9	16.368	+0.6
	b[b]	8	6.32	0.32	50.56	+0.9	16.176	−0.6
	A				50.08		16.272	
Carbon dioxide	a	8	6.65	0.36	29.20	+1.8	10.512	+1.8
	b[b]	8	6.52	0.36	28.16	−1.8	10.136	−1.8
	A				26.68		10.324	
Ethylene	a	2	0.15					
	b[b]	2	0.01					
C_3	a	2	2.45	1.075	4.90	0	5.268	−3.3
	b[b]	2	2.45	1.15	4.90	0	5.634	+3.3
	A	2			4.90		5.451	

[a] 10 in. = 1 mV.
[b] The fractogram is given in Fig. 8.

centrations..." is already an outmoded conception. Besides this, the new, highly sensitive techniques of gas chromatography will further help in its wide-spread application in air pollution studies.

Super-Sensitive Gas Chromatography

The two most significant developments in gas chromatography in recent years are the capillary or Golay columns named after the inventor,[28–30] and the ionization detectors developed in 1957–58 by Lovelock[34–37] and by Harley and McWilliam.[39,40] These new developments raise the capabilities of gas chromatographic instruments and it could be predicted that they will also be significant in air pollution studies.

The *Golay columns* are capillary tubes (stainless steel, copper, glass, or nylon) 150 ft, or more, in length by 0.010 in. in inside diam which are coated on the interior surface with an oil or grease similar to the liquid phase used at the packed columns. The resolutions obtained with these columns is of order of magnitude better than with packed columns: theoretical plates well over 100,000 can be reached resulting in two main advantages over regular packed columns: (1) a certain Golay column shows excellent resolution for different types of organic compounds which cannot be separated on *one* packed column; (2) even samples with wide boiling ranges can be analyzed in a relatively short time and with a good separation effect both at the beginning and end of the chromatogram. Zlatkis,[31] Condon,[32] and Desty[33] gave excellent examples of the application of Golay columns to the analysis of hydrocarbons and other organic materials.

The Golay columns require detectors of very small volume, short time constant, and high sensitivity. Because it would be very difficult to inject these very small sample volumes, a useful device, called a steam splitter, is used in connection with the Golay columns allowing standard syringe or gas valve introduction of sample into the instrument.

The two *ionization detectors* are based on the same principles: the organic molecules of the column effluent are ionized when entering the detector. The resulting ion current changes the electrical conductivity between two electrodes. This change will be recorded as usual resulting in a standard chromatogram.

The *hydrogen flame ionization detector* makes use of a small hydrogen flame in which organic molecules are ionized by thermal excitation. The carrier gas is nitrogen which has a high ionization potential so that it does not produce any "background" signal.[43]

The *β-ray ionization detector* contains a small radioactive source and argon is used as carrier gas. On entering the detector cell, argon is excited by the radioactively emitted electrodes into a metastable state and the organic molecules are ionized by collision with the excited argon atoms.

Using the ionization detectors, the minimum detectable concentration is much lower than with thermal conductivity detectors. The data given by McWilliam[41] for the sensitivity of the various detectors can be expressed in the following comparative numbers:

Sensitivity of the thermal conductivity detector: 1
Sensitivity of the β-ray ionization detector: 10^3
Sensitivity of the flame ionization detector: 10^7

Other authors do not confirm McWilliam's data; for instance the comparative sensitivity values of Thompson[42] and Ongkiehong[43] are as follows:

Thermal conductivity detector: 1
β-ray ionization detector: 50
Flame ionization detector: 10^4

But, even these data are enough to make possible the direct analysis of trace impurities in parts per million concentrations without any previous condensation and in one run using ionization detectors and Golay columns. Recently completed investigations[46] indicate the superiority of the flame ionization detector over the β-ray ionization detector in minimum detectability and linearity.

These new tools of super-sensitive

Table II—Analysis of the Impurities in Electrolytic Hydrogen with 2 m Molecular Sieve 5A Column with the Condensing System

The conditions of the analyses are given in Fig. 7.
Sample volume: (a) = 1000 cc; (b) = 960 cc (Fig. 7); (c) = the data of (b) converted to 1000 cc sample.
A: Average values of (a) and (c).

Component	Analysis	Attenuation (S) of the 1 mV recorder	Peak height (H), in.	Peak width at half height (W), in.	Peak height at max attenuation[a] (S × H), in.	Deviation from the avg. peak height %	Peak area at max attenuation (S × H × W), sq in.	Deviation from the avg. peak area, %
Oxygen	a	8	2.35	0.09	18.80	+1.3	1.6920	+1.3
	b	8	2.20	0.09			1.5840	
	c	8	2.29		18.32	−1.3	1.6496	−1.3
	A				18.56		1.6708	
Nitrogen	a	128	6.90	0.16	883.20	+0.2	141.3120	−2.0
	b	128	6.60	0.16			135.1680	
	c	128	6.87		879.36	−0.2	147.2000	+2.0
	A				881.28		144.2560	
Methane	a	128	2.60	0.28	332.80	0	93.1840	−0.1
	b	128	2.50	0.28			89.6000	
	c	128	2.60		332.80	0	93.3376	+0.1
	A				332.80		93.2608	
Carbon monoxide	a	2	1.50	0.52	3.00	+1.7	1.5600	−1.4
	b	2	1.40	0.52			1.5400	
	c	2	1.45		2.90	−1.7	1.6040	+1.4
	A				2.95		1.5820	

[a] 10 in. = 1 mV.

gas chromatography are relatively young and, therefore, until now no publication has appeared which uses these devices especially in the air pollution field but it can be predicted that they will find wide-spread application in the near future.

The principles of the flame ionization detector were the basis for developing a completely new instrument which accurately detects and measures fractions of parts per million concentration of organics in gases in a few minutes. Because this instrument was designed specifically for air pollution studies, a short description of the instrument is included in the final part of this paper. Two recent papers[44, 45] dealt in detail with the construction, performance, and evaluation of this instrument.

Analyzer for Trace Organics in Gases

The Model 213 Hydrocarbon Detector is designed for the detection and analysis of trace quantities of hydrocarbons and other organics in inorganic gases. The instrument rapidly and accurately measures the concentration of the total amount of organic material from as low as 0–1 ppm full scale to 7% full scale.

The heart of the instrument is a *flame ionization detector* designed especially for this purpose (Fig. 9). It consists of a tubular aluminum block in which four openings are tapped at right angles to the axis to provide entrance for the flame jet, and igniter filament, a thermocouple (to check the presence of the flame) and a tube as vent. Two axial bores are tapped through the detector: the first is sealed with a cup but can be removed for access to the interior elements if necessary; the second contains an electrode placed opposite to the flame. The detector house serves itself as the second electrode.

The instrument differs in two respects from a regular gas chromatograph. First, it does not contain any chromatographic column and, therefore, provides the measurement of the total concentration of the organic substances present in the sample. Second, no carrier gas is used; the matrix gas itself serves as carrier gas flowing continuously through the detector during the analysis. This results in a constant deflection of the panel meter proportional to the concentration of the organic pollutants.

The flow schematic of the instrument is given in Fig. 10. The instrument contains four lecture size gas cylinders, making it independent from the outside services.* These four gases are: *hydro-*

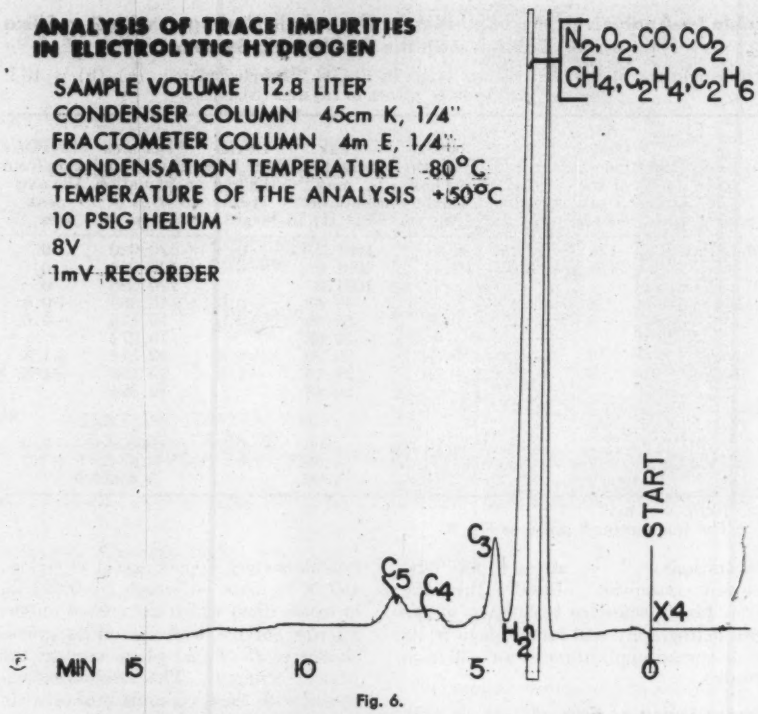

Fig. 6.

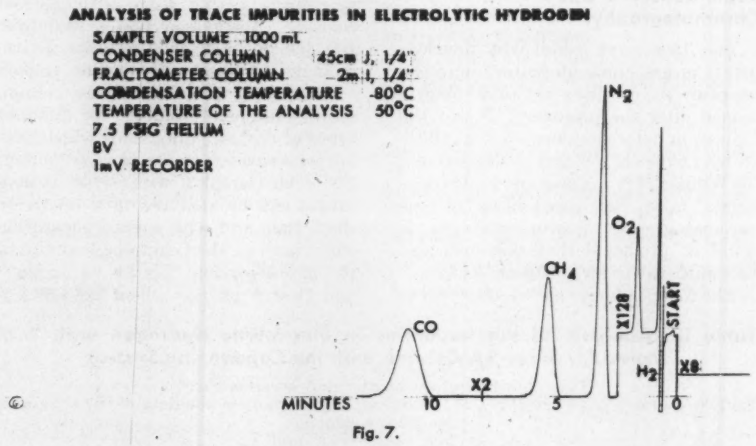

Fig. 7.

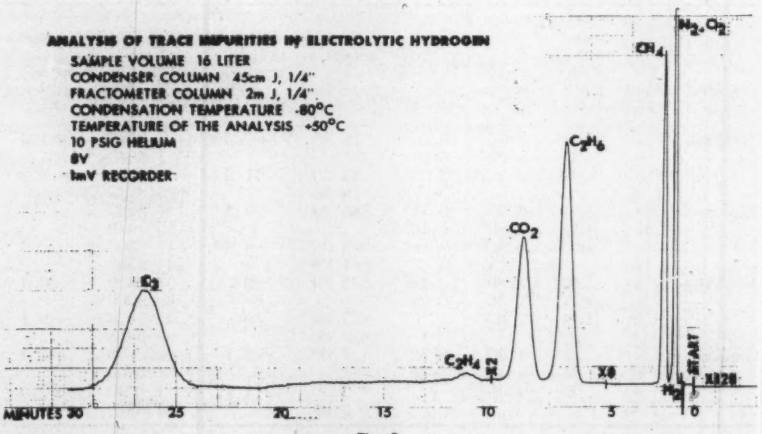

Fig. 8.

* Auxiliary bulkhead fittings on the front panel permit the optional use of external gas supplies if a semi-permanent installation of the instrument is anticipated.

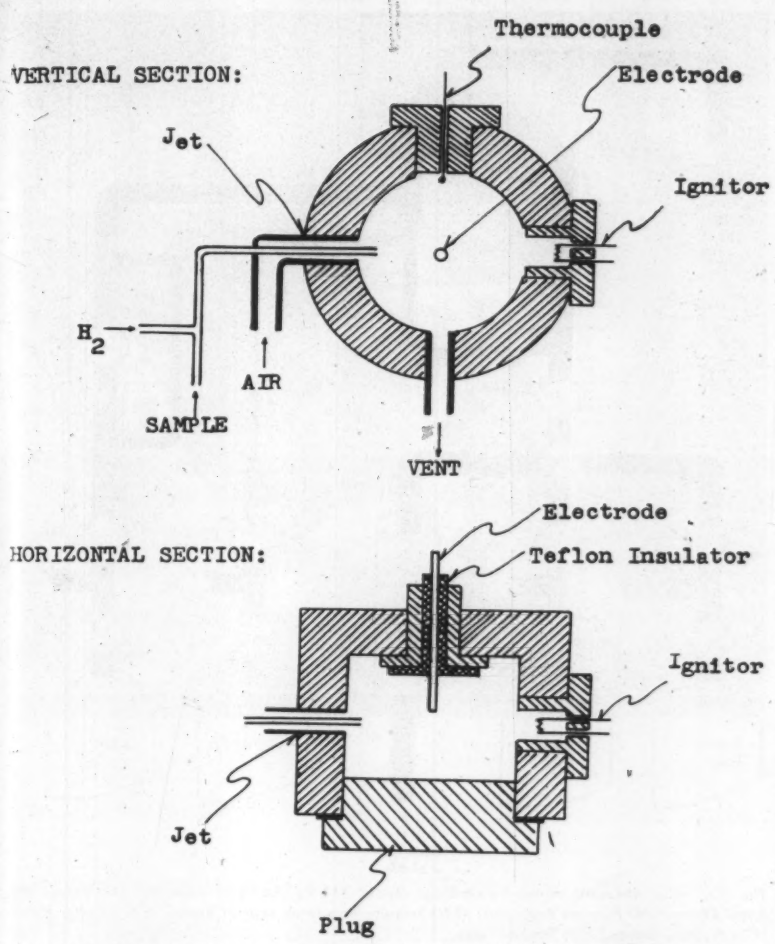

Fig. 9. Flame ionization detector for the Perkin-Elmer Model 213 hydrocarbon detector.

gen and air, to maintain the flame in the detector, a *test gas* with a concentration in the same order of magnitude as the sample to permit proper calibration of the panel meter, and a *zero gas* (the same as the background gas) which is necessary in the higher sensitivity ranges or if the background gas is hydrogen, oxygen (with the possibility of introducing a variation in flame parameters), or helium (with a relatively high thermal conductivity which may alter the flame temperature).

The instrument is a completely self-contained unit. Batteries provide for the necessary electrical power. An electrometer tube and a transistor amplifier are built into the instrument to drive a 1 milliampere meter on the front panel. The range of the instrument can be changed by switching resistors in the grid of the electrometer tube in steps of 10, from 1 to 1000. The instrument also provides for use of an external galvanometer recorder if necessary.

The instrument is installed in a portable aluminum cabinet of 12 × 24 × 10 in. in size with a total weight of 47 lb. Figures 11 and 12 are photos of the instrument under transport and operation.

The instrument requires the introduction of samples at pressures above atmosphere: generally in the range of 5–15 psig. Unpressurized samples may be introduced with a simple hand, or motor-driven pump of an oil-less type (since the instrument will measure any contaminants added by the pump). In some cases (particularly in automobile exhaust gas analysis) only samples at low pressures are available and it is not possible to pressurize the sample gas before entering the instrument. For this purpose, a special modification of the instrument was developed which allows the introduction of samples at 0.25–2.5 psig pressures.

The operation of the instrument can be described briefly as follows: first, the valves of the hydrogen and air are opened and the pressures adjusted to the proper value. The flame is ignited and checked with the thermocouple. Then, the zero meter reading is adjusted and the test gas is conducted through the detector; the full scale meter deflection is adjusted by selecting the proper resistance and regulating the flow rate of the test gas. If necessary, the zero position can be rechecked by using the zero gas in place of the test gas. Finally, the sample is introduced under a proper pressure by turning the selector valve and the concentration of the organic pollutants is read on the meter as a percentage of gas concentration with which the instrument was standardized.

The instrument detects all of those components in which carbon is bounded to hydrogen, halogen, or other carbon atoms. That means that it is *specific for organic compounds* and has no response for the inorganic gases including CO and CO_2 and water. This fact is important for two reasons. First, because it allows the direct flow of the sample through the detector and the inorganic matrix gas serves as "carrier gas" without any background response. The second advantage is that water vapor, or inorganic contaminants (e.g., H_2S, COS, NH_3, nitrogen oxides) do not interfere with the response of the organic pollutants.

The linearity of the detector's response is excellent as shown in Fig. 13 which presents the results obtained with blends of normal hexane and nitrogen.

Finally, a very important characteristic of the flame ionization detector should be mentioned: its response is in general *proportional to the number of carbon atoms* in the molecule. That means, that, e.g., the response for butane in equimolar concentration is four times that of methane. This phenomenon is true generally if analyzing hydrocarbons (paraffins, olefins, cycloparaffins, acetylene, benzene). However, when other atoms or groups are substituted for hydrogen in the molecule, the relative response of the detector will differ more or less from that obtained in analyzing the corresponding paraffinic hydrocarbon. Table III illustrates this phenomenon presenting the detector output for a given concentration of each material as a fraction of detector output obtained at the same conditions for the same con-

Table III—Response of Substituted Organic Substances as Fraction of That for Paraffinic Hydrocarbon of the Same Carbon Number in the Same Molar Concentration

Material	Response
Methyl alcohol	0.58
Ethyl alcohol	0.69
Acetone	1.02
Methyl chloride	0.83
Carbon tetrachloride	0.67
Methyl trichlorosilane	0.93
Trimethyl amine	0.58

centration of paraffinic hydrocarbon of the same molecular carbon number.

The Table illustrates that although the response of the instrument is not perfectly independent of molecular species, for the hydrocarbons it is very nearly so. In this case, the detector may be considered essentially a carbon atom counter since its output is proportional to the sample's total carbon content. Because substitution of other atoms for hydrogen reduces the fraction of a given compound ionized under given conditions, in precise quantitative work such as in gas chromatography, calibration factors for various organic compounds will probably be necessary. However, it is highly improbable that this effect will seriously militate against its utility in those fields of application in which it is expected chiefly to be used and where the main contaminants are always hydrocarbons.

The instrument described above is expected to find wide application in many fields of gas pollution analysis. The tremendous scope of its application is only suggested by a few typical examples: measurement of unburned hydrocarbons in automobile exhaust gases; measurement of low-level hydrocarbon contamination in Lox and other high purity cryogenic gases used in missile, aviation, and allied fields; measurement of the level of air pollution and lower explosive limits in mines, and in a broad range of process industry environments; study and control of combination equipment efficiency; leak checking in packaging, gas transmission lines, storage areas, and refrigeration systems; monitoring for toxic or explosive concentration of solvents or process chemicals; measuring the contamination level in vehicular tunnels, garages, and other enclosures and measuring relative contribution of automobile exhaust to air pollution on or near parkways and high traffic density areas.

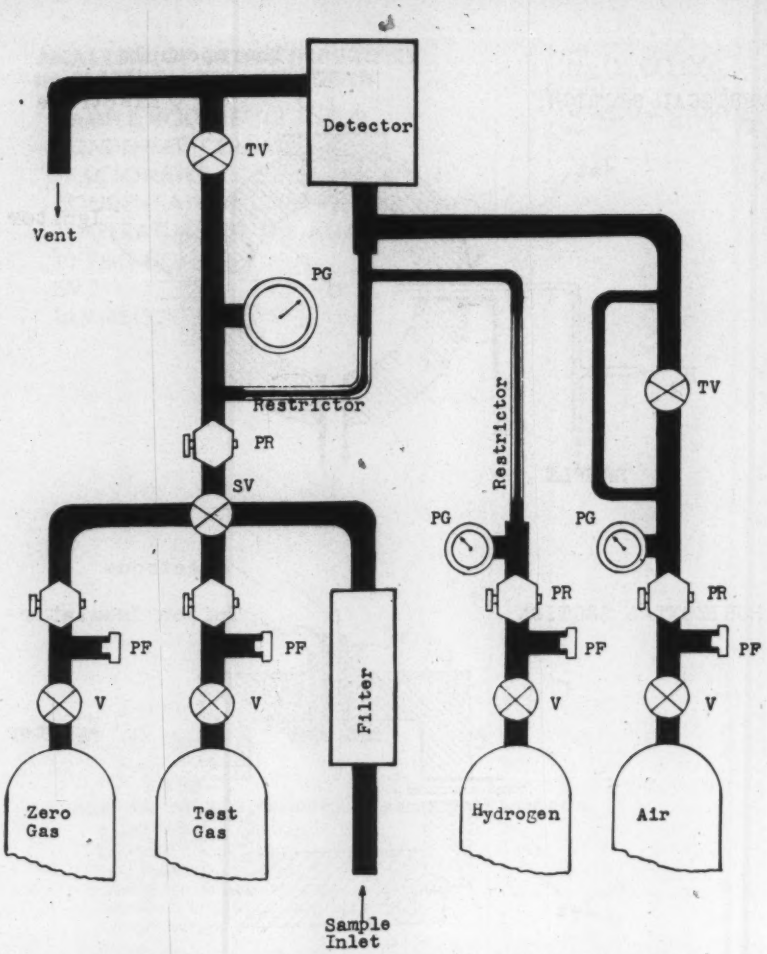

Fig. 10. Flow schematic of the Perkin-Elmer Model 213 hydrocarbon detector. (V) Valve; (PF) Panel Fitting; (PR) Pressure Regulator; (PRr) Pressure Regulator, rear of panel; (SV) Selector Valve; (PG) Pressure Gauge; (TV) Toggle Valve.

Summary

The modifications on conventional gas chromatography apparatus are described which allows the use of gas chromatography in air pollution studies. The newest developments of supersensitive chromatography are described with special respect to their importance in trace analysis. The construction, and operation of a new instrument based on the flame ionization principles is detailed.

Additional Comments

Wide Range Analysis

Besides the use of multiple-stage instruments, the temperature programming of the chromatographic column is another possibility to solve the problem of the analysis of a sample with a wide boiling-point range. In this case, the column temperature is (linearly) programmed during the analysis which accelerates the elution of the higher components from the column and diminishes in this way the time of the analysis. The temperature programming became quite popular in some fields, and, without any doubt, it is sometimes really a powerful tool. It has, however, one limitation: the number of (packed) columns which are selective in a wide range, or which can be used on higher temperatures is very limited, and most "high temperature columns" are not very selective for isomers, particularly in the lower boiling range.

Super-Sensitive Gas Chromatography

The ionization detectors can also be used with packed columns; in this case, no split is necessary and in this way, trace impurities can be easily detected. The combination of packed columns with the hydrogen flame ionization detector can also find an excellent application in the air pollution control because the flame ionization detector does not show any response for inorganic gases, and therefore, e.g., trace hydrocarbon impurities in air could be analyzed easily quantitatively.

The truth of this statement is illustrated in Fig. 14. A two meter packed column was used with a standard flame ionization detector in a Perkin-Elmer Model 154-D Vapor Fractometer; $^1/_4$ cc

Fig. 11.

Fig. 12.

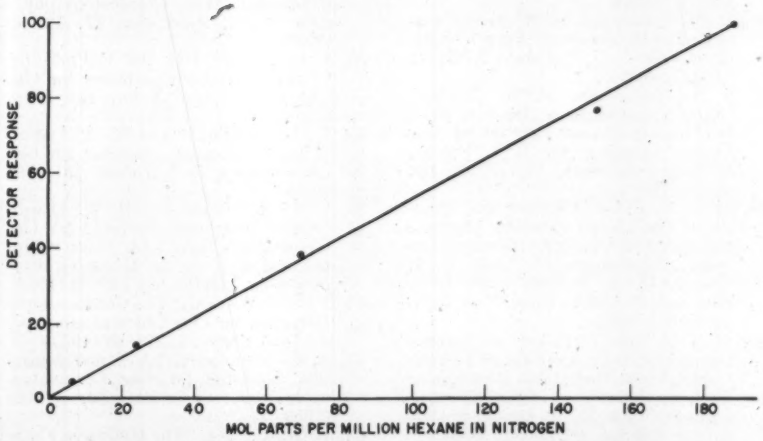

Fig. 13 Results obtained with blends of normal hexane and nitrogen.

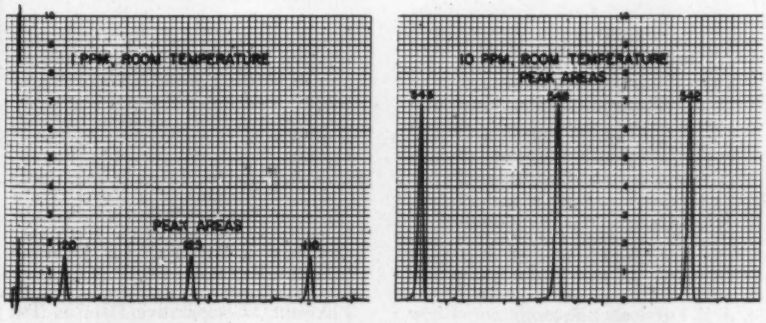

Fig. 14. Flame detector sensitivity: propane in argon 1/4 cc sample.

of the sample was injected into the equipment with the help of the standard gas sampling valve, and the effluent of the column was conducted directly into the detector. The sample contained one and five ppm propane in argon, respectively, as indicated in the figure. The numbers over the peaks give the peak areas. The run with the sample containing one ppm propane was made on the highest sensitivity, the other run with attenuation x2. Because samples of one cc volume or maybe more could be used in similar runs, the minimum detectibility of this system is well below one ppm.

Further, the new detectors have another very important future: an ionization detector and a thermal conductivity detector can be used parallel to each other in one gas chromatograph, by using two recorders. The Perkin-Elmer Model 154-D Vapor Fractometer, e.g., is designed to allow the use of both detectors and both (packed and Golay-) columns parallel (Fig. 15). In this way, it is possible to carry out a complex analysis of an air sample in one run: the flame ionization detector will detect the trace concentrations of organic impurities and, at the same time, the thermal conductivity detector would record the analysis of carbon monoxide or carbon dioxide or other inorganic gases of interest.

Analyzer for Trace Organics in Gases

It was mentioned that a special modification of the Model 213 Hydrocarbon Detector was developed for automobile exhaust studies which allows the direct introduction of the low pressure sample into the analyzer. Figure 16 shows the schematic of this modification. The necessary pressure of the sample is only four inches of water.

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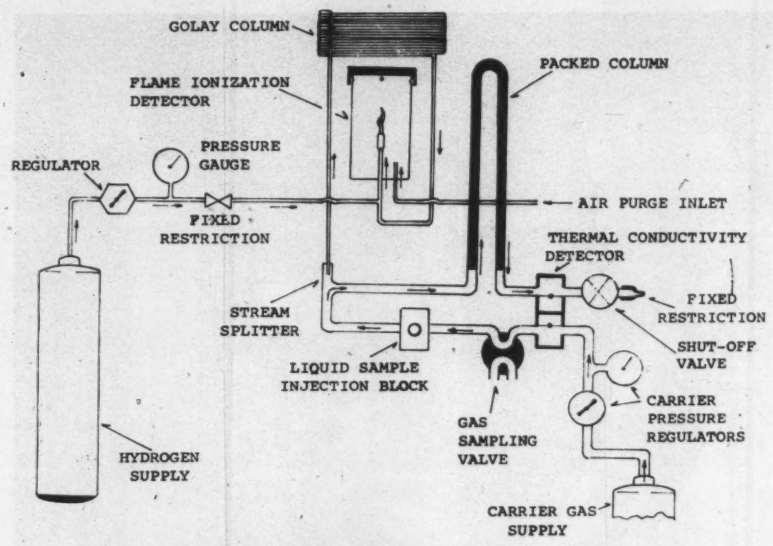

Fig. 15. Golay and packed columns—flame ionization and thermal.

PERKIN-ELMER MODEL 213
HYDROCARBON DETECTOR
MODIFIED FOR
LOW PRESSURE SAMPLING

V	Valve
PF	Panel Fitting
PR	Pressure Regulator
PG	Pressure Gauge
TV	Toggle Valve
FR	Flow Regulator

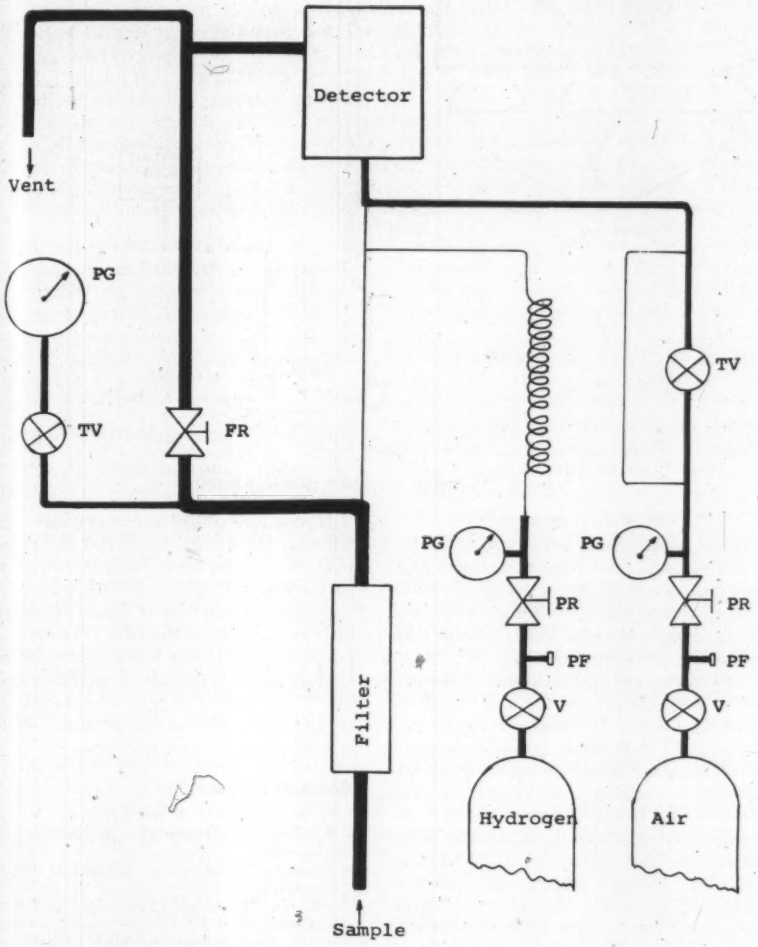

Fig. 16.

sented at the Third Gas Chromatography Symposium, Edinburgh (June 8–10, 1960).

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New Type Incinerators Eliminates 'Bugaboos'

Smoke, unburned vapors, and fly ash from backyard incinerators—major contributors to smog in many metropolitan areas—have been virtually eliminated in an improved type of gas-fired household incinerator described by Battelle Institute research engineers at the Fall Conference of the Building Research Institute in Washington, November 16. Factors involved in the design of the incinerator were the subject of a technical paper prepared by Richard B. Engdahl and Glen M. Hein.

The improved incinerator was developed jointly by the American Gas Association Laboratories and Battelle, under the sponsorship of the American Gas Association.

Key features of the new design include: *(1)* a high-heat, gas-fired afterburner with separate air supply which operates at 1500°F to completely oxidize smoke and odors, *(2)* controlled supply of combustion air to regulate rate of burning and minimize loss of fly ash, and *(3)* sufficient input of heat from gas flame to completely burn all combustible refuse, including wet garbage.

The American Gas Association has offered the results of the research program to incinerator manufacturers, encouraging them to incorporate features of the improved design in their products in order to meet municipal air-pollution requirements. Many household incinerators now in production have been redesigned to include these improvements and, as a result, have been accepted for use in such cities as Chicago, Detroit, Cincinnati, and Columbus.

Welcome New Members

INDIVIDUAL MEMBERSHIPS

Booker, Eugene R.
San Francisco, California

Doyle, John L.
Minneapolis, Minnesota

Fanning, Thomas F.
Buffalo, New York

Marshall, Carl A.
Bridgewater, Connecticut

Middleton, John T.
Riverside, California

Olaf, John
Dormunderstr. 151, Germany

Rodman, Clarke A.
Providence, Rhode Island

Scivally, Robert H.
Los Angeles, California

Pyl, Chester A. Vander
Providence, Rhode Island

SIMPLIFIED METHOD IN FINDING OZONE

(*Continued from p. 33*)

since this gives an integrated approach to the values obtained, and will make comparative studies between areas more realistic, as far as the evaluation of contamination levels are concerned.

The correlation between oxidant levels as obtained by automatic instrumentation, and the ozone levels as obtained by the method outlined in this paper show the applicability of this method in conducting studies on the levels of air pollution in community surveys. It is definitely useful in determining locations for more sophisticated instrumentation. Moreover, where used as standard routine test, it would definitely show whether levels of ozone pollution are increasing or decreasing.

Acknowledgment

The authors wish to thank Ken Middleham, University of California, Riverside, for the photographs used in this report.

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ANNUAL SEMINAR TO BE HELD SOON

The Seventh Annual Radiological Health Seminar at the University of North Carolina, Chapel Hill, will be conducted by the School of Public Health and the North Carolina State Board of Health on January 30–31, 1961. The theme of this Seminar will be "The Concept of Total Dose Assessment." Dr. K. Z. Morgan of the Oak Ridge National Laboratory and Dr. Richard Chamberlain of the University of Pennsylvania and Dr. Jan Lieben of the Pennsylvania State Health Department will be among the instructional staff. Personnel of the Public Health Service, the University, and the State Health Department will do laboratory and seminar instruction. Address inquiries to: Professor Emil T. Chanlett, P. O. Box 899, Chapel Hill, North Carolina.

SOAP-MAKING ODOR CONTROL

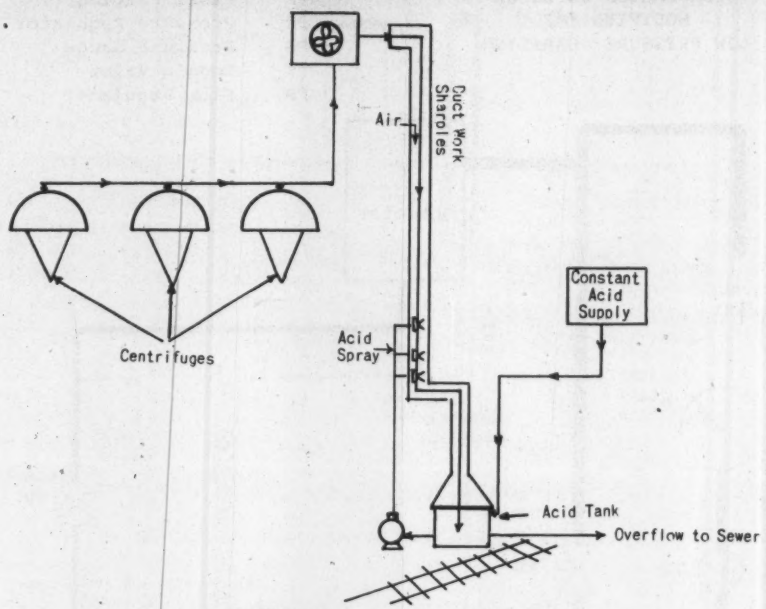

Fig. 8. Control of odors from centrifuge room.

(*Continued from page 13*)

rine or ozone, combustion and catalytic combustion, odor counteracting, and scrubbing with a strong inorganic acid. Combustion and scrubbing were selected largely because of availability and economic considerations.

Pressures of neighborhood residents were an ever-present consideration in this situation. It could not justifiably be argued that these complaints were not valid, and there was certainly an air pollution ordinance in effect. Nevertheless, to simply have submitted to these pressures and invoked the ordinance seemed unfair in view of the earnest, though unsuccessful (at the time) efforts of the company to control their problem. Since no one could tell the company exactly how to solve the problem, trial and much error were inevitable.

How unfortunate for everyone—the citizens, the community, and the company—it would have been if, through premature use of legal authority, the company would have had to cease business and leave the city! There can be no doubt that the lesson of co-operation, patience, and justice as illustrated here is at least as important a contribution of this paper as the technical solution of a unique odor problem.

Acknowledgments

1 G. H. Packwood Manufacturing Co. for technical assistance and preparation of diagrams.
2 Richard J. Collins for analytical determinations.
3 Charles M. Copley, Jr., for technical assistance.
4 E. C. Brockmiller and L. F. Klein for technical assistance.
5 Health Education Section for visual aids.

AIR POLLUTION CONTROL PROGRAM

(*Continued from page 8*)

panies in their own pollution abatement programs. We are giving prompt press coverage to Smoke and Fumes-sponsored research papers. And we are developing authoritative statements which will assist oil men in handling questions or complaints received at local or state levels.

As the Information Program grows, other projects will be developed. Further study is being given to six of these. They include articles for national magazines, leaflets for oil company employees, distribution of a running progress report on air pollution control activities, circulation of pertinent magazine or newspaper articles, and efforts to interest magazines in publishing interviews with persons who play prominent roles in the anti-pollution battle.

At the American Petroleum Institute we believe the objectives and projects I have outlined backstop the research program by leading to better understanding of the problem and of the progress being made toward its solution. In working toward this solution we are fully aware of the important role played by you gentlemen and by your Association. To you and to the Association we give assurance of full co-operation by the United States oil industry in fulfillment of our joint mission.

★ ★ ★ Section Hi-Lites ★ ★ ★

Niagara Frontier Section

A Niagara Frontier Section meeting was held at the Sheraton-Brock Hotel on October 27 and was conducted by Vice-Chairman Amery. Ernest R. Gedeon reported on the group visit made by New York State Health Department Air Pollution Control Board representatives; and Dr. L. A. Vendetti, Cleaner Air Week Chairman, made a committee report.

The speaker was Dr. M. W. First, Industrial Hygiene Consultant. His speech was on Air Sampling and he defined the purpose of air sampling as the ascertainment of the nature, concentration, duration of evolution, and extent in a given area of air contaminants. Because the analysis of an air pollution situation can be no better than the sample upon which it is based, accurate sampling is vital.

As an alternative to stack sampling, automatic continuous samplers are available but because of the high cost of such units they cannot be widely used. Even the U. S. Public Service has drastically curtailed its sampling program.

Mid-Atlantic Section

Air pollution control is becoming a matter of increasing public concern. Such was the consensus of business leaders, scientists, educators, and government officials assembled at the ninth Air Sanitation Technical Conference sponsored by the Mid-Atlantic States Section of the Air Pollution Control Association.

Featured as speakers were J. P. Sheehy, Taft Sanitary Engineering Center; Dr. G. E. Pendray, Public Relations Consultant; Henry Walter, New York World Telegram and Sun; Jack Smith, City Planning Commission; W. J. Ingram, N. Y. U. College of Engineering; Kenneth Kowald, New York City Department of Air Pollution Control; Dr. R. A. Prindle, U. S. Public Health Service; and Dr. R. M. Manganelli, Rutgers University, Department of Sanitation.

In opening the morning session, J. P. Sheehy reviewed the existing training curricula in the air pollution control field. Sheehy stated "not enough young men have shown an interest in the air pollution courses offered by the universities. Perhaps we in the air pollution control field are to blame for not sufficiently glamorizing the field by publicizing its importance."

Dr. Pendray noted that "public relations can never serve as a substitute for sound technical remedies. But the employment of technology alone may not assuage the anger of the community once it has been aroused. Only when proper technology has been combined with sound public relations can the company be reasonably sure of getting out and keeping out of trouble."

Henry Walter discussed the role of public media in communicating air pollution news. He said, "repetition in publicity and advertising helps." According to Mr. Walter, "The press some time ago wrote that Consolidated Edison Company was spending millions on air pollution control in its stations but he thought, 'So what! Why don't they clean up the stack discharge from their East River Station?' After reading a number of similar news stories, however, he realized that Con Edison was spending millions on boiler conversions and eventually would get around to straightening out the problems at its East River plant. Repetition had gotten across Con Edison's message."

Jack Smith noted that dustfall has an important impact on neighborhood planning and is considered carefully by the City Planning Commission. "Whether we can attract middle-income groups back to the City depends partly on the dustfall issue. Clean cities will also attract new industries," he added.

During the afternoon session, Professor Ingram discussed "engineering management of the air resource" and suggested that levels of performance should be directed to the community's need and safety.

Kenneth Kowald called for frankness in discussing control problems with the public: "There are three good reasons for telling the truth about air pollution: we owe it to the people who pay our salaries; we are going to be caught up with at some time or other, anyhow; and, we need the support of the mass media, and through it the public's support to keep alive and to keep working for cleaner air."

Dr. Prindle then discussed medical aspects of air pollution citing increased industrialization and urbanization as the source of the problem. "A matter of growing public alarm, the government and industry will spend $15 million in 1961 on air pollution research and $30 million per year by 1968," he said.

The final speaker, Dr. Manganelli, emphasized the need "to keep abreast of the present situation and also look

(*Continued on p. 47*)

API LAUNCHES RESEARCH PROGRAM FOR NEW EQUIPMENT

A far reaching program of research, directed toward new and improved equipment using distillate fuel was launched today by the American Petroleum Institute. The new program constitutes a major effort in the oil industry's drive to improve the convenience and appeal of liquid fuel in heating the nation's homes.

The over-all objectives of the new research program are to develop, interpret, and disseminate new technical information that will assist manufacturers in providing improved equipment using distillate fuel.

This major step to expand fuel-oil markets was authorized today by the API Board of Directors meeting in Chicago. The research program will be initiated in 1961 under the direction of the API Division of Marketing. Under the program co-operative efforts of the entire oil industry will be integrated by top industry specialists in fuel-oil combustion.

In a report to the API Fuel Oil Committee, J. L. Minner of Shell Oil Company described the background and plans for the new research program, which he called "an investment in the future of oil heating." Mr. Minner is chairman of the Research Subcommittee charged with the over-all planning for the program, as part of the API's broad effort in expanding fuel-oil markets.

Mr. Minner outlined the several areas of activity incorporated in the program to aid in the development of improved distillate consuming equipment. The program will:

1 Search for new principles in fuel-oil combustion
2 Search for greater understanding of combustion principles, both new and old
3 Search for ways of exploiting these principles
4 Demonstrate principles in bench-scale or prototype equipment
5 Interpret research results in terms of their practical application to combustion equipment
6 Solve problems which present major obstacles to development of new equipment
7 Communicate needed information to developers and manufacturers to stimulate final development and commercialization of equipment

"Research will be undertaken under the API program only in those areas in which needs are not likely to be met

(*Continued on p. 47*)

Personalia

Robert F. Stewart has been elected a vice president of Joy Manufacturing Company and general manager of the Western Precipitation Division, Los Angeles, it was announced by L. G. Helmick, executive vice president of Joy. Mr. Stewart has been assistant general manager of Western Precipitation division for the past year. Since joining the company in 1946 he has been divisional vice president, sales manager, manager of proposal and contract, and a sales engineer for the division—major producers of industrial dust and fume collection equipment for air pollution control.

* * *

Carroll F. Hardy, associate director of the NCA Marketing Department, has been elected a Fellow of The American Society of Mechanical Engineers, an honor reserved for outstanding authorities who have made distinguished contributions to the advancement of engineering. A member of ASME since 1943, he was promoted to the grade of Fellow, August 31, in recognition of achievements in the technology of coal utilization that have benefited fuel users, community relations, and the national effort to conserve natural resources.

Mr. Hardy is Chairman of APCA's By-Laws Committee as well as a member of the American Institute of Mining and Metallurgical Engineers, and Engineering Society of Cincinnati. Mr. Hardy is one of the few engineers who has been chairman of both the Coal Division of AIME and the Fuels Division of ASME. He is now liaison officer between Bituminous Coal Research and the Marketing Department of NCA.

* * *

Logan E. Davis has been appointed Manager, Mining Industry Sales for Western Precipitation Division of Joy Manufacturing Company by P. W. Zilliacus, general sales manager of the division.

Mr. Davis is a graduate of the Montana Schools of Mines and a member of the American Institute of Mining Engineers. His experience includes several years in the Ventilation and Industrial Hygiene Department of one of the nations major mining companies where he gained extensive experience in mine and plant dust and fume control. He also worked with Joy Manufacturing Company as Senior Application Engineer of the Standard Fan and Dust Collector Department.

More recently Mr. Davis was employed as Manager of the Ventilation, Dust Collection, and Air Conditioning division of a well known concern dealing with the mining, metallurgical processing, and rock products industries.

With his headquarters at the Joy Manufacturing Company, Mining & Construction Division office at Salt Lake City, Utah, Mr. Davis will also serve as Manager of the Salt Lake City office of Western Precipitation Division. He will be responsible, in conjunction with the San Francisco Western Precipitation Division office, for negotiations for all Western Precipitation Division products in the trade areas covered by Butte, Montana, Salt Lake City, Utah, Denver, Colorado, and El Paso, Texas sales offices.

* * *

Carl A. Marshall, formerly vice president-sales for Warner Collieries Company, Mammoth, West Virginia, has joined the engineering staff of the Air Pollution Control Division of the National Coal Association.

Harry C. Ballman, manager of the Division, said Mr. Marshall would become field engineer for the eastern district with temporary headquarters in Bridgewater, Connecticut. Mr. Marshall succeeds George W. Biven, who resigned.

Mr. Marshall, who has been associated with the coal industry since 1929, served as managing director of the Fairmont Coal Bureau, a market promotion group with headquarters in New York, before going to Warner Collieries. Warner Collieries was sold to The North American Coal Corp., Cleveland, last year.

(*Continued on p. 47*)

CATALYTIC COMBUSTION BECOMES SUBSIDIARY

Catalytic Combustion Corporation, of Detroit, Michigan, announced that, through mutual exchange of stock, they have become a fully owned subsidiary of Universal Oil Products Company of Des Plaines, Illinois.

Universal Oil Products is a recognized leader in the fields of petroleum refining and petrochemical research technology; UOP platforming, fluid catalytic cracking hydroforming, and other catalytic processes are licensed for use by refiners throughout the world. Now, by combining Catalytic Combustion Corporation's developments—all-metal catalysts, catalytic fume combustion, heat and power recovery, process gas purification, and catalytic infrared generation—the widest possible range of catalyst applications are brought under one corporate structure.

Catalytic Combustion Corporation will continue to operate from its Detroit offices.

CITIES, COUNTIES, DISTRICTS TO BE HELD RESPONSIBLE IN ANTI-SMOG ENFORCEMENT

The Bay Area Air Pollution Control District Directors has decided to leave the enforcement of anti-smog regulations to the 67 cities, six counties, and 32 fire districts that comprise the District. However, the Bay Area APCD "retains regulatory responsibility with uniform services and enforcement carried out by local jurisdictions," in accordance with the recommendations submitted by the County Administrators.

Linsky Submits Recommendations

Control Officer Benjamin Linsky was directed to submit his recommendations, in line with the new enforcement policy, to the Board's budget and finance committee for study. The Committee's recommendations regarding an increase in the present tax limit of one cent per $100 of assessed valuation will be presented to the full Board at the December 7, 1960, meeting. Mr. Linsky has asked for an immediate increase for a minimum enforcement program which would cost at least $1,000,000 annually. In his report to the Board, he justified every proposed new addition to the staff.

Testimony Given

Before reaching its "home rule" enforcement decision, the Directors heard testimony from three representatives of industrial Contra Costa County. Dr. Hendrick Blum, health officer of the county, contended that there is a need for local smog enforcement to "counterbalance the strength and position of the District." Harry Morrison, secretary-manager of the Contra Costa Taxpayers' Association, was critical of the tax increase provision in the Control Officer's report. William O'Connell, a consulting engineer, and also a member of the District's Advisory Council, also voiced his opinion in favor of local enforcement.

Walker Speeds Up Draft

District legal counsel Matthew Walker was directed to speed the draft of a model ordinance for the cities and other agencies within the District's jurisdiction as a necessary step to local enforcement of Regulation 2, which became effective January 1, 1961.

The Board unanimously voted to file the Ernst and Ernst management survey of the District's operations, and directed that it be used as background and reference for the future.

UNIVERSAL OIL COMPANY CERTAIN OF QUALITY IN SMOG-CONTROL MUFFLER

Universal Oil Products Company is confident its Purzaust smog-control muffler will meet California requirements, according to M. P. Venema, president.

The UOP president told the New York Society of Security Analysts that plans are under way to market the muffler when it is certified for use.

"Universal has offered Purzaust to the recently organized California Motor Vehicle Pollution Control Board for testing and certification," he said. "When this testing takes place, we are confident that Purzaust will be certified."

Working With Stanford Research

He pointed out the company has formed Universal Oxidation Processes, Inc., Los Angeles, to supervise manufacture and sale of the muffler for used cars. Universal also has an agreement with Arvin Industries, Inc., to help reach auto manufacturers, covering the new car market.

Universal is working with Stanford Research Institute on development of methods to test exhaust gas purifiers; results of the study are expected "to facilitate the certification of Purzaust."

Purchase last week of Catalytic Combustion Corp. by the Des Plaines, Illinois, process research and development company, plus Purzaust development, will enable UOP "to develop important earnings from the entire field of atmospheric pollution control."

PERSONALIA

(*Continued from p. 46*)

Dr. Jerry McAfee, formerly vice president of engineering for Gulf Oil Corporation's Manufacturing Department, has accepted the newly created office of vice president executive technical advisor.

On a world-wise basis, Dr. McAfee will report to Gulf's top management as to results of technical studies concerning a variety of activities.

API's Program Plays Major Role

(*Continued from p. 45*)

by independent effort of manufacturers. Activities in the API program will be carried to the point of demonstrating principles, but not to the point of providing final equipment design. Manufacturers will be encouraged to complete the development of final details, leading to the introduction of new commercial products. The API program is intended to supplement, rather than to replace, efforts of equipment manufacturers," Mr. Minner said.

Last year Mr. Minner's Subcommittee contracted for the services of a research team at Battelle Memorial Institute, headed by D. W. Locklin to make a comprehensive study to appraise the specific research and development needs of the oil-heating equipment industry. This study was recently completed and received enthusiastic endorsement.

The research study and subsequent planning of details for the new research program has had the active guidance of a Technical Advisory Group.

SECTION HI-LITES

(*Continued from p. 45*)

ahead to the future." He felt that motivation to correct the air pollution problem must come from the top management of industries.

The Conference was held in mid-November at the Con Edison office building at 4 Irving Place. George T. Minasian, Director of Community Relations at Con Edison, delivered the welcoming address.

WANTED!

Your editor would like to start a section for Control District news. We ask the co-operation of each control district in sending news releases into headquarters for publication in the JOURNAL.

CALENDAR

January 23–26, 1961	41st Annual Meeting of American Meteorological Society, New York, New York.
January 30–31	Seventh Annual Radiological Health Seminar, University of North Carolina, Chapel Hill, North Carolina.
April 18–20	International Symposium on Chemical Reactions in the Lower and Upper Atmosphere, San Francisco, California.
June 11–15	**54th Annual Meeting of APCA, Hotel Commodore, New York, New York.**

PANTEX MANUFACTURING HERALDS ACQUISITION OF RIGHTS TO MONOXIT

The acquisition of exclusive manufacturing and sales rights to Monoxit, an automobile engine exhaust gas purifier, was confirmed by Pantex Manufacturing Corporation of Pawtucket, Rhode Island with their announcement of plans to aggressively pursue it in conjunction with Tel-A-Sign, Inc. of Chicago, Illinois.

On August 31, Pantex Manufacturing (Canada) Ltd., a wholly owned subsidiary of Pantex Manfacturing Corporation, acquired "a substantial interest" in Tel-A-Sign, Inc. by the purchase from the company of a large block of stock.

William F. Grossman and A. A. "Bill" Steiger, the respective Presidents of the two companies, stated that production and marketing of the device will be a joint venture under a wholly owned Pantex subsidiary, the Monoxit Pantex Corporation, now being formed.

The Monoxit Exhaust Purifier, under intensive development for nearly 15 years, embodies a unique combination of direct flame afterburner and catalytic converter in a compact, easy-to-install unit, no larger than three inches in its major dimension, which is ingeniously attached directly to the exhaust manifold under the hood of an automobile.

First patented in 1953, Monoxit has since been extensively altered and refined to achieve optimum efficiency with maximum production and installation simplicity and many additional patents on this work are in process. As finally resolved, it will operate efficiently, without maintenance, for the life of a normally maintained car.

The retail price of the device is expected to be substantially under $50.

James A. Graham, designated as President of Monoxit Pantex, said, "We have run exhaustive tests during our evaluation of Monoxit, both in our facilities and in conjunction with qualified independent laboratories, to determine product effectiveness. We are satisfied that Monoxit will provide economical and efficient performance as required to substantially reduce the air pollution effects of carbon monoxide and unburned hydrocarbons from automobile engine exhausts.

"Monoxit's introduction will mark one of the first production breakthroughs in bringing a perfected exhaust fume purifier on the market," Mr. Graham continued, "and is, by independent evaluation, a most effective practical solution to the exhaust fume purification problem."

Environmental Survey for Plant Site

Table V—NPD 2 Environmental Survey—Ottawa River Sediment (1959)

Location	No. of Samples	Range of Beta-Gamma Activity, $\mu\mu$C/g DW[a]
Site	30	38.5–53.5
11 mi downstream	18	55.0–69.9
12.5 mi downstream	18	40.7–57.5
14.5 mi downstream	18	42.6–73.0

[a] Based on efficiency of counter for K-40.

(*Continued from p. 18*)

been confined to the collection of grass samples from pastures and the collection of snow-shoe rabbits (*Lepus americanus*). Samples of the bone, flesh, and thyroid of the rabbits have been counted for gross radioactivity and samples retained for further analysis if this should later prove necessary. The rabbits are collected at four sampling stations within a 2-mi radius of the reactor. Milk samples will probably also be taken. The results of the assaying of samples so far collected are given in Tables I to V.

Acknowledgments

I am greatly indebted to I. L. Ophel who has supplied much background information and the data quoted in the figures and tables.

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ACTIVITIES IN REVIEW

(*Continued from p. 4*)

Membership Campaign

Larry Faith's letter has already received very fine response. One week after his letter was sent out, almost 100 replies have been received. As of November 30, 1960, the membership count is as follows:

Sustaining	102
Company	251
Individual	1557
Total	1910

This represents an increase of over-all membership since the annual meeting, from 1811, or 100. This figures reflects losses since the annual meeting, so the actual number of new members is greater. We are looking for the membership committee's campaign to greatly accelerate the increase.

CLASSIFIED

AIR POLLUTION ENGINEER—Vacancy with the State of Hawaii Department of Health, Bureau of Industrial Hygiene. Requires one year of work experience in the design, construction, or alteration of fuel-burning equipment and a bachelor's degree in mechanical, chemical, sanitary or civil engineering. Appointments to this position may be made at any step between $6,792 to $8,664 per annum. For further information and application, write to the Department of Personnel Services, State of Hawaii, 825 Mililani Street, Honolulu 13, Hawaii.

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CAW ACTIVITIES—BRING RESPONSE FROM WIDE AREA

Nearly 100 cities in 28 states, the Dominion of Canada and Mexico, participated in APCA's Cleaner Air Week, which took place from October 23 to 29, 1960.

Fifty cities co-operated in the nation's meteorological experiment Project Air Lift. Principle objective of the project was to call public attention to the relationship of local weather conditions to sanitation of the atmosphere. Results of the experiment will serve to illustrate nature's role in the creation of air pollution problems.

The helium-filled pilot weather balloons were released during Cleaner Air Week in each 50 key industrial areas for the experiment. Each balloon was accompanied by a card to be mailed upon recovery to Charles Howlton, national chairman of the Cleaner Air Week Committee, who will prepare final performance tabulations before APCA's next annual conference.

32 Balloons Found

Already 32 cards have been returned by finders of the CAW pilot balloons. One of the balloons released at Columbus, Ohio, traveled 310 miles southeast to Meridithville, Virginia. Another released at Dayton, Ohio, was found 220 miles southeast, near Bluefield, West Virginia. Three of those released at Cincinnati were found 14, 20, and 36 miles southeast of release point. Youngstown, Ohio, reports two of their balloons were 37 miles and 135 miles west southwest of release point. Providence, Rhode Island, balloons were found one-half mile southeast and 25 miles southeast of release point, another 17 miles, traveled northwest.

These are preliminary tabulations which emphasize the effect of prevailing winds and air turbulence on the dispersal of contaminants in the atmosphere.

Many CAW Activities

Project Air Lift was only one of many local activities sponsored during Cleaner Air Week. Others included public conferences on air pollution problems, displays of control equipment, and sampling devices which are being in a scientific approach to air pollution control.

Cleaner Air Week is part of the Association's efforts to further the knowledge and practice of air pollution control. If you have any suggestions or ideas for CAW activities, please let us hear from you.

54th ANNUAL MEETING

JUNE 11–15, 1961

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OPEN FOR SUGGESTIONS

The time is fast approaching when a new president and five new APCA Directors will be elected by the membership. You, as an individual member or company representative member of APCA, are requested to submit to the chairman or any member of the Nominating Committee, names of individuals and the offices for which you feel they are qualified. These recommendations should be received before March 1, 1961.

The members of the Nominating Committee and their addresses are as follows:

Ralph W. Bourne, Chairman
Chief Engineer
Air Pollution Control District
Jefferson County
304 City Hall
Louisville, Ky.

Richard J. Ruff, President
Catalytic Combustion Corp.
4544 Grand River Ave.
Detroit 8, Mich.

Harry C. Ballman, Director
Air Pollution Control Department
National Coal Association
Marketing Division
Coal Building
1130 17th Street, N.W.
Washington 6, D. C.

Richard F. O'Mara
O'Mara and Flodin, Inc.
1111 Wilshire Blvd.
Los Angeles 17, Calif.

James H. Carter
Smoke Commissioner
City Hall, Room 419
St. Louis 3, Mo.

The offices for which this committee is to select nominees are:

1. President—to serve one year.
2. Eight Directors—to serve according to the following schedule:
   Two control officials to serve three years.
   One control official to serve two years.
   One control official to serve one year.
   One representative from research, educational, and consultant category to serve three years.
   Three industry representatives to serve three years.

Retiring Board members are: Dr. Leonard Greenburg, research, educational, and consultant category; Louis E. Bunts, Richard E. Hatchard, Ralph W. Bourne, and Raymond Smith, control officials; C. C. Tate, petroleum, Max W. Lightner, steel, and John M. von Bergen, equipment—industry.

The large number of Board members who are being elected is occasioned by the change in by-laws two years ago combined with the re-alignment of the Board due to Dr. Greenburg's change in employment category.

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It operates on the same principle as the Air Sampler, but is fitted with an air filter to remove suspended solids; and the tape assembly is enclosed to prevent blackening of the tape, outside the sample spot.

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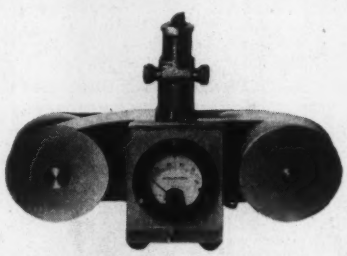
Write for descriptive bulletins that give complete construction and performance details of both the samplers and the Spot Evaluator.



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